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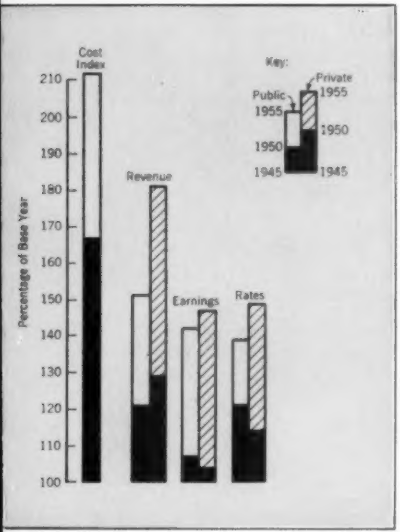
AMERICAN WATER WORKS ASSOCIATION

In this issue:



1945–1955: Everything on the up and up

Journal

AMERICAN WATER WORKS ASSOCIATION

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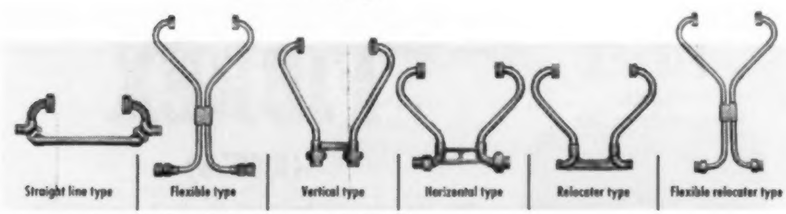

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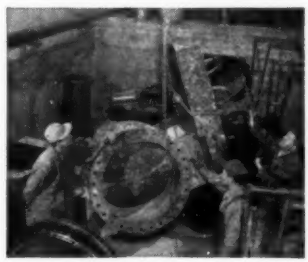

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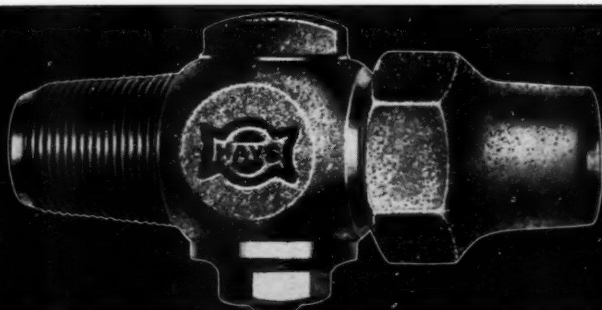

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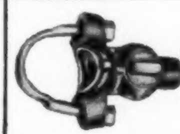

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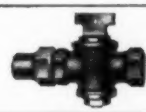

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Journal

AMERICAN WATER WORKS ASSOCIATION

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Control of Odor and Taste in Water Supplies

E. A. Sigworth

A contribution to the Journal by E. A. Sigworth, Chemist & Technician, Industrial Chemical Sales Div., West Virginia Pulp & Paper Co., New York, N.Y.

PROPER disinfection of water supplies has been so successful throughout the United States that citizens now expect a safe water without question. Public demand for a palatable water as well has resulted in greater attention to the correction of tastes and odors. Although many water plants are now delivering a consistently palatable water to their consumers, much remains to be done. Abel Wolman, *(1)* in his report on 75 years of water quality improvement, stated:

> The road to universally palatable water, however, has been only partially traversed, even though suitable control methods are available. Some operators refuse to admit their responsibility to their consumers, while others laugh off complaints, and still others do not know that the water they are delivering is unpalatable. John Baylis' statement in 1924 is still applicable in many communities today and is worthy of repetition. "The removal or prevention of [objectionable tastes] should receive more consideration from our water works officials."

There are many progressive water works officials throughout the United States, however, who are showing an increasing willingness to spend whatever is necessary to reduce tastes and odors to palatable levels. During 1956 the city of Chicago *(2)* expended nearly $150,000 for activated carbon to control tastes and odors at the South District Filtration Plant. This expenditure represented about 25 per cent of the entire chemical costs, whereas the cost of chlorine for disinfection was only 16 per cent. Thus, this plant is spending more money to accomplish water palatability than is necessary to make the water safe for human consumption. Responsible officials are so proud of their accomplishments that they have adopted the slogan, "Every Drop Pure and Palatable." Wide variations in activated carbon dosages are necessary to control fluctuations in odor types and intensities. The annual average dosage at the Chicago South District Plant was only 2.0

ppm, yet the maximum daily usage during 1956 was 47,080 lb, equivalent to 24 ppm. The daily average output of this plant during 1956 was 338 mgd.

Importance of Palatability

Flavor in the foods people eat and drink is determined by the combination of their senses of taste and smell, and the food industry is heeding public demand for products with the most satisfying flavor. Some companies have even developed flavor panels of several hundred people, widely dispersed throughout the country, in an effort to learn consumer preference for flavors in the foods they produce. By utilizing the information obtained, companies have been able to increase their sales appreciably.

The modern grocery store in the United States stocks many different brands of tomato juice from which the consumer may select the one he prefers for flavor. If none of these brands is acceptable, the consumer has additional choices of vegetable or fruit juices to satisfy his specific desires. The consuming public in the United States is demanding and buying those foods and beverages which are most pleasing to the senses of sight, taste, and smell. Costs seem of only secondary consideration, considering the wide acceptance of frozen foods and the continued purchase of coffee during the period of skyrocketing prices. Today, many housewives are purchasing a specific brand of soap merely because it, or the wrapper, happens to blend in with the color scheme of the bathroom, and cost is of practically no significance. Certainly, with such an attitude, the public cannot logically object to minor increases in water costs which will assure the delivery of a consistently palatable water.

In order to obtain opinions of leaders in the field, a questionnaire dealing with importance of water palatability was submitted to a selected group of state health officials. A number of the responses stressed that an unpalatable water could constitute a health menace if consumers were so dissatisfied that they would obtain drinking water from local springs or wells which, though more palatable, would be of questionable safety.

The practice of fluoridation of water suplies to aid in the reduction of dental caries has been adopted in a large number of communities throughout the United States. Effectivesness of the treatment depends upon a consistent and relatively uniform ingestion of the fluoridated water. Therefore, water palatability assumes major importance if the desired beneficial results are to be assured.

Except for air, water is the most vital requirement for human existence. Some members of the medical profession in the United States have advised that the normal individual should have a water intake of 2 qt of water per day. Complying with such advice would constitute no problem where a consistently palatable water was available.

Although the USPHS standards state "The water shall have no objectionable taste or odor," there appears to be considerable difference of opinion among state health officials regarding the legal requirements for water palatability. In the above-mentioned questionnaire, the state health officials were asked whether they would have the legal right to go into a treatment plant where unpalatable water was being supplied and insist on application of suitable corrective treatment. Fifty per cent answered yes, 30 per cent no, and the remainder were either uncertain or

would not give a definite answer. Thus, it would seem that there is no consistent action on the part of state health departments with regard to water palatability.

The problem of taste and odor correction has, therefore, remained predominantly at the local level, where great improvements have been accomplished. Whether motivated by consumer complaints or a sincere desire to deliver the best water quality possible, many local water works officials can now boast that their consumers are receiving palatable water from sources which are frequently subject to high concentrations of odorous substances. Concerted effort on the part of state departments could not help but aid materially the cause of universally palatable water.

Physiology

A new technique is now being used in the United States in an effort to determine how the senses of taste and smell function (*3*). This involves recording electrical responses of the taste cells, as well as the olfactory, by tapping into the specific nerve fibers. With the delicate instruments now available, it is possible to "listen in" on the messages as they are being carried to the brain.

From the experimental data, obtained from many different kinds of animals which were subjected to many tests, a theory has been developed on how people taste. The theory involves adsorption and ion-exchange principles, and an equation has been developed to cover various taste responses. These studies confirm the previous theory that there are only four taste sensations—salty, sweet, sour, and bitter—and that all other so-called tastes are actually odors.

Studies on the olfactory responses have just recently resulted in the development of methods of quantitative measurements, but a satisfactory theory has yet to be developed. Tests show that the trigeminal nerve fibers do not enter the mucous layer covering the olfactory epithelium. Since no specialized structures are known to exist at these nerve endings, just how they are stimulated by odors remains a mystery.

Such extensive studies would probably have greater significance for foods and beverages, where flavor is an essential factor. In their proper environment an individual can enjoy the aroma of fish, cucumber, geranium, and even newly mown hay; yet he would be highly critical of a potable water containing any of these odors.

The public expects water to be free from any detectable taste or odor when it is used for cooking, bathing, or drinking purposes. Thus, complete removal is not necessary, but taste- or odor-producing substances must be reduced to concentrations which are below detectable levels. Based on the fact that there are only four taste sensations, information later in this article will show that the predominant problems of water palatability in the United States are those of odors rather than tastes.

Summary of Questionnaires

The meeting of the International Water Supply Congress in May 1958 will include in its program a panel discussion on control of odor and taste in water supplies, and the author has been delegated as reporter for the United States on this subject. In order that the report be more than just one person's opinion, questionnaires were prepared on various phases of the subject for submittal to water works officials

concerned with the problem. Selection of individual plants was greatly simplified by data contained in a survey conducted by the USPHS, with the cooperation of state health departments, encompassing water facilities existing as of Jan. 1, 1955, in communities of 25,000 population or over. In summarizing data from this survey, Ralph Porges (*4*)* reported that 202 plants of a total of 570 were employing corrective treatments for taste and odor control. These specific plants, therefore, constituted a core for development of the desired information. To broaden the scope of the coverage, questionnaires were submitted to additional plants where corrective treatments such as use of activated carbon, free residual chlorination, and chlorine dioxide had been utilized for improvement of water palatability. Responses were amazingly good, totaling 241 and representing a return of more than 65 per cent. Average daily pumpage for all of the plants totaled more than 5 bil gal. Thus, the average daily output was 20.7 mil gal, and the median daily output was 7.4 mil gal.

Some questionnaire responses indicated that tastes and odors no longer constituted a problem, and these were eliminated immediately. Therefore, all references to the questionnaires will involve only those actually having taste and odor problems. Table 1 shows the summary of the number of plants reporting the cause of odors due to algae, decaying vegetation, trade wastes, and others. The table also shows the number of plants reporting successful treatments employed for correction of the specific sources of odor. The total of the individual treatments is greater than the number of plants reporting for the specific cause, because some plants reported more than one suc-

TABLE 1

Successful Treatments of Tastes and Odors at 241 Plants

Cause	Plants		No. of Plants Employing Method Successfully*				
	No.	%	Activated Carbon	Free Residual Chlorination	Super Chlorination	Chlorine Dioxide	Aeration
Algae	198	82	163	17	7	6	5
Decaying vegetation	162	67	139	17	6	6	2
Trade wastes	92	38	56	12	3	26	3
Other	55	23	47	11	2	3	1
			Percentage Employing Method Successfully†				
	No. of Plants						
Algae	198		82	8.6	3.5	3.0	2.5
Decaying vegetation	162		85	10.5	3.7	3.7	1.2
Trade wastes	92		61	13.0	3.3	28.2	3.3
Other	55		85	20.0	3.6	5.5	1.8

* Some plants have employed more than one method successfully in combating a particular cause of odor. Therefore, the total number of instances of successful treatment may exceed the number of plants reporting the specific cause.

† Percentage figures are based on number of plants reporting a particular cause, not the total 241. A total of percentages in any given row may exceed 100 per cent.

* See also this issue, p. 1567.

cessful treatment. For example, in the treatment of trade wastes some plants faced a variety of problems, and they therefore reported chlorine dioxide successful for some types and another treatment for others.

The most frequent cause of tastes and odors is algae, with decaying vegetation a rather close second. Table 1 shows these same results in percentages, and it will be noted that algae are reported by 82 per cent and decaying vegetation by 67 per cent.

Algae

Since algae are most frequent causes of tastes and odors, a separate questionnaire was submitted to those reporting algae as a problem. This questionnaire was developed by selecting from a table published in *Water Quality and Treatment* (5) those algal types for which characteristic odors were recorded. Responses to this algae questionnaire were less numerous, because some plants were not equipped to make microscopic examinations or had little concern because the water source was a stream or large lake where treatment would be impractical. Nevertheless, 152 responses were received and Table 2 summarizes the data from those plants reporting experiences with the specific algal types.

The organisms most frequently reported ar the Diatomaceae, with the Protozoa and the Cyanophyceae groups practically tied for second. Those in the fungi group are of only minor significance.

TABLE 2

Odor-producing Algae Reported *

Organism	Times Reported	Organism	Times Reported
Diatomaceae	*321*	*Chlorophyceae*	*114*
Asterionella	102	Dictyosphaerium	6
Cyclotella	29	Eudorina	16
Diatoma	42	Gloeocystis	9
Meridion	7	Hydrodictyon	5
Synedra	93	Nitella flexilis	0
Tabellaria	48	Pandorina	17
		Staurastrum	26
Cyanophyceae	*198*	Volvox	35
Anabaena	91		
Aphanizomenon	52	*Protozoa*	*205*
Clathrocystis	12	Bursaria	0
Coelosphaerium	29	Ceratium	33
Cylindrospermum	5	Cryptomonas	6
Rivularia	9	Dinobryon	48
		Glenodinium	13
Fungi	*26*	Mallomonas	23
Beggiatoa	6	Peridinium	16
Crenothrix	19	Synura	66
Sphaerotilis natans	1		

* Other organisms mentioned were: Anabaenopsis, Ankistrodesmus, Anuraea, Chlamydomonas (reported three times), Chlorella, Cladothrix, Codonella, Coelastrum, Cyclops, Daphnia, Euglena, Fragilaria (reported eight times), Gallionella, Leptothrix, Melosira (reported eleven times), Merismopedia, Micractinium, Microcystis (reported three times), Microspora, Navicula, Oedogonium, Oscillatoria (reported three times), Palmella, Pediastrum (reported nine times), Raphidomonas, Scenedesmus (reported five times), Sphaerozyga, Spirophyllum, Stephanodiscus (reported four times), Stigeoclomium, Tetraspora, and Trachelomonas.

The individual algal types most frequently recorded are *Asterionella, Synedra,* and *Anabaena.* Somewhat less frequently mentioned are *Diatoma, Tabellaria, Aphanizomenon, Dinobryon,* and *Synura.* It is interesting to note that little or no mention was made of *Nitella flexilis, Bursaria,* and *Sphaerotilis natans.*

Provision was made in this questionnaire to write in other algal types responsible for tastes and odors. At the bottom of Table 2 those write-ins are listed.

This algae questionnaire also asked whether there was any disagreement as to the character of odor associated with the individual algal types. Predominantly there was agreement with the characteristic odors with but a few exceptions, as follows:

1. *Asterionella:* A number reported experiencing the fishy odor, without encountering the aromatic or geranium odor.
2. *Anabaena:* One reported this to give a geranium odor, while several reported the odor to be vile pigpen.
3. *Aphanizomenon:* Several different descriptions were offered for odors associated with this type, including nasturtium, pigpen, dry musty, and corn husks.
4. *Ceratium:* Several described the odor as cod liver oil or bitter.

TABLE 3

Odor Types Due to Decaying Vegetation *

Characteristic Odor	No. of Plants Reporting
Musty	69
Earthy	28
Woody	20
Moldy	17
Swampy	12
Grassy	9
Fishy	8
Wet leaves	7

* Others mentioned to a lesser degree are septic, muddy, boggy, vegetable, phenol, peaty, rotten, putrid, soaked straw, very sour, varnish, barnyard, and horse urine.

Based on recent work in this country, J. K. G. Silvey (*6*) reports that actinomycetes are responsible for many odors encountered in raw water supplies. In fact it has been indicated that many of the odors attributed to algae are actually caused by growths of actinomycetes which are present in the water. Therefore, those answering the algae questionnaire were asked to express an opinion as to whether they agreed with this view. This concept appears to be too new for any final opinion since 40 voted yes, 39 voted no, and 32 had formed no opinion. Actinomycetes are extremely small organisms requiring much greater magnification than is required for microscopic examination of algae. Few water plant laboratories would be likely to have the necessary equipment for studies of acactinomycetes, so the greater majority of views expressed are probably opinions based on experiences with algae rather than any actual data on actinomycetes.

Decaying Vegetation

Odors under the classification of decaying vegetation derive from: decaying algae, leaves, weeds, or grass; seepage from stagnant areas into reservoirs or streams; flushing of stagnant areas and farm land during spring freshets or heavy rainfall periods; and any disturbance of bottom deposits in streams or impounded supplies due to sudden raising or lowering of the water level.

Many reported the types of odors arising from decaying vegetation, and these are summarized in Table 3. It will be noted that the most prevalent descriptive term is musty, while the anticipated descriptions of swampy, wet leaves, and moldy, fall far behind. A close examination of the descriptive

terms at the bottom of the table will indicate the imaginative character of some of the observers. It is quite within the realm of possibility that many of these odors may actually be due to the presence of actinomycetes.

Trade Wastes and Others

Table 4 shows types of trade wastes causing tastes and odors in water supplies. Phenol is reported most frequently, with chemical second. Trade wastes occur less frequently than odors of natural origin, but often give rise to extremely high odor concentrations. Some of these odors are more difficult to adsorb on activated carbon, so higher dosages are required.

TABLE 4

Frequency of Trade Wastes Causing Odors *

Types of Waste	No. of Plants Reporting
Phenol	38
Chemical	20
Petroleum oil or oil refinery	18

* Others less frequently mentioned are dairies, corn sugar plants, canneries, mine wastes, sulfite paper mills, and vitamin wastes.

The most frequent listing in the classification of other causes is sewage, with 22 reporting. Second is the muddy earthy type odor associated with high turbidity, with nine reporting. Less frequently listed are synthetic detergents, actinomycetes, dairy farms, fish, and silt and mud deposits.

Deoxygenation

Of 159 plants reporting on the question of deoxygenation, only 31 reported having odor problems. Many of the reporting plants, however, derive their water from streams and shallow reservoirs, where such a problem would not exist. According to some comments, a flat, earthy taste developed under a heavy ice coating at several locations, and odor was eliminated by activated carbon or aeration. Many reported development of septic or hydrogen sulfide odors, and some a swampy odor. One plant reported that a cool rain and hail storm broke up the thermocline, giving rise to fishy, haylike, musty, and earthy odors.

Odors Within Plants

Only about 30 per cent of the 159 reporting plants reported the development of odors within the treatment plant, and many of these have been eliminated by various means. The greater majority reported facing difficulties with decomposing sludge in settling basins. Corrective measures include more frequent cleanings, installation of sludge removal equipment, feeding activated carbon or chlorine at the basin influents, and the addition of carbon when refilling basins. Algae have been reported to develop in presettling basins, and copper sulfate was the corrective treatment.

Very few reported any problems with odor development in the filters. Instances involved overchlorination of water entering the filters and algae or decomposing sludge on the filters. One report indicated that the application of ammonia ahead of filtration, followed by postchlorination, gave rise to a serious algae problem in the filters. This was corrected by moving the point of chlorine application ahead of the filters. Isolated examples of odor development within the treatment plant include improper combustion of the carbon dioxide producer, temperature turnover of water in the basins, recirculation of primary sludge, and lime softening giving a strong fishy odor.

Underground Supplies

The presence of dissolved minerals in underground water supplies poses a taste problem in some water supplies.

In general, most sections of the United States have little difficulty, but there are a few localized sections where such problems exist. A great majority are caused by the dissolving of minerals from the underground strata, resulting in high chlorides, sulfates, hydrogen sulfide and iron. Also, some few cases of salinity due to salt water intrusion have occurred. A great majority of waters giving difficulty with iron and hydrogen sulfide are suitably treated by aeration, followed by either chlorination or retention for completion of oxidation. No economically successful treatments for chlorides or sulfates have been reported. Some communities develop a tolerance for slight mineral tastes, but where such tastes are very severe, those supplies are almost always abandoned in favor of more palatable ones.

Demands for water are pyramiding because of increased population, greater per capita consumption, and shifts of population away from urban areas. Underground water sources are so depleted in some populous areas that additional demands will have to be met by resorting to surface supplies, which will probably require treatment for correction of tastes and odors.

Treatment and Distribution

The greater number, 69 per cent of 159 plants, reported development of odors or tastes due to treatment chemicals. Seventy-nine per cent of the plants having problems reported chlorinous odors. Many of these have corrected the conditions by using chlorine with ammonia, activated carbon, closer control of chlorine residuals, or dechlorination. Thirty-nine per cent reported medicinal odors due to chlorophenols, and 15 per cent reported odors due to nitrogen trichloride. Other chemical influences were chloralgal odors, fixation of odors by lime, hop odor from carbon dioxide, and bitter taste due to chlorine reaction with detergents. Suggestions offered in cases of chlorinous odors were to let water run a few seconds and to let water stand for a few minutes.

Of 159 water supplies reporting, only 49 per cent reported having problems of tastes and odors arising in distribution systems. The preponderance of odor problems within the distribution system occur in low-velocity areas and were usually successfully corrected by a suitable flushing program. Less than 15 per cent of those reporting indicated problems caused by pipe coatings or organic growths in the pipelines. Of very minor significance is the development of odors in new iron or cement pipes, sloughing off of deposits, tank coatings, algae in reservoirs, and disinfection procedures on new distribution lines.

Detection and Measurement

Of 241 plants reporting on odor evaluations, approximately 82 per cent run odor tests, and most of these run tests daily or more frequently.

Standard Methods (*7*) describes two basic procedures for odor evaluation. One procedure merely involves estimation of the odor, either hot or cold, whereby the odor intensity is given a value expressed in Roman numerals. A zero denotes a completely palatable water, and a value of V is a water so unpalatable that no one will drink it. Approximately 31 per cent of the reporting plants utilize this procedure.

The other standard procedure is the threshold dilution method, wherein samples of water are diluted with increasing amounts of odor-free water

until that dilution is obtained at which the odor is just detectable; 42 per cent of the reporting plants utilize this technique. The threshold odor number is obtained by dividing the total volume of the sample by the volume of odorous water contained therein. Thus an odor number is determined, which represents an actual measure of the odor concentration. In this test the water is usually carried to a temperature of 60°C in order to secure as high an odor value as possible. A threshold odor number of 2 is nearly always within palatable limits, and in the majority of cases a threshold number of 5 will constitute a palatable water. Sometimes, although odor concentrations are well within palatable limits, complaints associated with the sense of smell are still made. At such times appreciably lower threshold odor values must be reached in order to assure a palatable water.

Where taste tests are conducted, dilution procedures similar to the threshold odor technique are employed. Temperature of the water is usually kept at tap water temperature, although some few plants do utilize an elevated temperature.

The highest threshold odor numbers reported in the questionnaires were 12,500 and 6,000, but the mean maximum odor of raw water was only 30. The worst raw water had an annual average odor of 726, whereas the mean annual average of all plants was only eight.

For delivered water the highest mentioned was 278, with a mean maximum of 5. Thus, 50 per cent of the 90 plants reporting odor values are probably delivering a consistently palatable water. On an annual average basis, the highest reported value for delivered water was 19, with the mean at 2.

The maximum odor value is of greatest importance, because the average citizen in the United States will not soon forget the existence of an objectionable taste or odor in his water supply.

Corrective Measures

In the author's experience, first action for dealing with tastes and odors is for the treatment plant to institute chemical applications which are most likely to produce palatability, such as feeding the maximum possible amount of activated carbon, or adjustment of dosages of other chemicals to accomplish correction of the condition.

The next step is laboratory work to determine the most economical measures. A quantity of tap water containing the odor is dechlorinated for taste tests by a panel of observers, to determine the degree of odor removal necessary to reach palatable limits. Dilutions (20, 40, 60, 80, 90, and 100 per cent) of this dechlorinated water are prepared with odor-free water. These dilutions, at tap water temperatures, are tasted by several observers, starting with 100 per cent odor-free water and proceeding in the order of increasing amounts of tap water. Each observer tastes succeeding dilutions until he reaches the sample he considers unacceptable. The sample just previously tasted would thus constitute the acceptable palatability level for the specific observer. Based on observations of the panel, that dilution is selected which is acceptable to the greatest proportion of the observers, and the threshold odor of this dilution is determined to find what value must be reached in plant scale operations.

Laboratory tests are next conducted on raw-water samples with varying dosages of activated carbon (2, 5, 10,

and 20 ppm for low-odor concentrations; or 10, 20, 40, and 80 ppm for high), and the usual chemicals and treatments are employed to simulate plant operations. After filtration, threshold odors are run on each sample, and results plotted to determine the activated-carbon dosage necessary to obtain the previously determined threshold odor value for palatability. Since adsorption by activated carbon is much better on a large scale than in laboratory tests, only half the required laboratory dosage is applied in the plant. This dosage can then be altered to conform with plant results.

The above tests presume that existing points and order of chemical application will give optimum results. Complete studies would include an investigation to determine the influence of other chemicals, bearing in mind the following:

1. Chlorination can either reduce or intensify odors.
2. Better adsorption is usually obtainable if the odorous compound has not had an opportunity to react with chlorine.
3. Lime or other chemicals for pH adjustment can influence palatability.
4. For best results carbon should be applied to water having pH values below 8.5–9.0.

The city of Hammond, Ind. (*8*), employs a control system which has resulted in a 3-year period of operation without a complaint on taste or odor. Raw water is obtained from one of the Great Lakes, and odor sources originate on both sides of the intake. Thus, the specific odor to be treated depends upon the wind, and a sudden change in wind direction can completely change the odor conditions to be handled. Furthermore, the odor concentration has varied from 20 to 500 threshold odor units.

From actual plant experience graphs have been developed showing the activated carbon dosage necessary to control various intensities of each specific type of odor. Based on hourly threshold odor tests of incoming water, the dosage determined from the graph is applied to the raw water.

Hourly threshold odor tests are also conducted on samples collected at various points in the treatment plant. If the threshold value of water entering the filters is 3 or more, additional activated carbon is applied to the filter influent, and the dosage to the raw water is increased. As soon as the odor in the settling basin returns to normal, the application to the filter influent is discontinued. Activated carbon dosages at Hammond average 10 ppm, with a maximum of 125 ppm.

Preventive Measures

Many preventive measures are utilized to varying degrees for the control of tastes and odors. Copper sulfate is widely used for the control of algae growths, not only in impounded water supplies but also on occasion in settling basins within the plant and in open reservoirs on distribution systems. Decaying vegetation odors have been reduced in some cases by elimination of swampy areas on watersheds, either by dredging, draining, or damming off such areas from the main water supply. The greatest amount of effort, however, recently has been directed toward treatment of domestic and industrial wastes. Health authorities in the various states have been extremely active and much more insistent on proper treatment for domestic sewage which is discharged to a stream later used for potable purposes. To-

ward this end, the US Congress passed Public Law 660, authorizing federal grants of $500,000,000 for construction of sewage treatment plants. Many of the states have pollution control commissions, but the authority to act appears to be quite variable, depending upon the state laws involved and also upon individual watershed areas within the specific states. Some individual water departments have also taken steps to control the discharge of objectionable industrial wastes within their watershed area. Some of the results have been quite successful. One stream which was rapidly reaching the condition where it would be condemned as a public water supply is today so greatly improved that catfish and carp are now thriving where they were nonexistent for a period of at least 20 years. Naturally, the water quality at the plant intake was greatly improved and more amenable to treatment.

Application of chlorine gas at water depths up to 85 ft or chlorine solutions at greater depths were successful at Los Angeles, Calif., in appreciably reducing the tastes and odors developed in deoxygenated areas of deep reservoirs. Presence of chlorine or dissolved oxygen prevented anaerobic conditions in the thermocline area.

Chlorine gas was applied from the shore through small-diameter (¼ in.) black-iron pipe to a diffuser near the deepest point in the reservoir. Based on the amount of water in the thermocline area, chlorine dosages were quite high, but not unreasonable, considering the total water volume (9).

A specially designed aeration device (10) has been used successfully to break up stratification in a reservoir. Air was released through spargers 8 ft below the water surface at a rate of 160 cfm. The total 80 mil gal in the reservoir was theoretically turned over in about 13 hours, but complete elimination of stratification was only accomplished after a 7-day period of operation, as measured by uniform water temperature and dissolved oxygen. This result permitted use of water from all depths of the reservoir.

The questionnaire submitted listed treatments as follows: activated carbon, free residual chlorination, superchlorination, chlorine dioxide, ozone, aeration, and others. Individuals were asked to check various treatments tried and to comment on the results obtained. A few failed to furnish the desired details, but the great majority were very cooperative.

The answers are summarized in Table 5. The first column shows the total number of plants reporting for the particular causes of odors. Succeeding columns record the degree of success reported for all listed treatments except ozone. Under the individual treatment, the first column shows those reporting complete success; the second column, partial success; and the third column, no success.

Activated Carbon

Powdered activated carbon was first applied in a public water supply in the United States in 1929, and was accepted almost immediately as a method for the control of odors in water supplies. Results shown in Table 5 indicate its success on the entire gamut of odors encountered. Some of those reporting partial success indicated reasons, such as inability to apply carbon at the proper point, or inability to apply sufficient carbon because of inadequate facilities within the treatment plant.

During the early development of powdered activated carbon, postchlori-

TABLE 5

Causes of Odors	No. of Plants Reporting	Activated Carbon (221)						Free Residual Chlorination (158)					
		Total		Partial		None		Total		Partial		None	
		No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Algae	198	163	90	17	9	2	1	17	13	56	44	54	42
Decaying vegetation	162	139	92	11	7	1	1	17	16	46	43	44	41
Trade wastes	92	56	68	23	28	3	4	12	19	22	35	28	45
Other	55	47	87	5	9	2	4	11	28	12	31	16	41
Overall summary	507	405	86	56	12	8	2	57	17	136	41	142	42

* Percentage figures are based only on those plants that reported having tried the specific treatment on the particular cause of odor. For example, on other causes of odor, chlorine dioxide was tried by 21 plants; therefore,

nation was the common practice, so results with carbon were very successful. With the advent of prechlorination, however, many plants fed activated carbon and chlorine at the same point, with a resulting loss in effectiveness of both chemicals. In spite of a wealth of literature recommending separation of points of application, questionnaire responses indicate that 35 per cent of the reporting plants are still applying the two chemicals at approximately the same point. The reason is perhaps less due to lack of knowledge than to inability to do otherwise, because of existing plant designs.

Application of carbon ahead of chlorine appears to offer the advantages of more successful adsorption of odors and an appreciable reduction in chlorine demand. Some 37 per cent of the reporting plants have adopted this order of chemical application.

Conversely, 28 per cent of the reporting plants are applying chlorine prior to carbon. Many of these report a long time interval, with a mean of 90 min between points of application. With such time intervals the interference factor would probably be of minor significance. Nevertheless, in such plants the potential of reduced chlorine demand by reversing the order of application should justify further study.

The highest reported dosage of powdered activated carbon was 180 ppm, with a mean maximum dosage of 30 ppm. Based on an overall yearly usage the average dosage was 2.1 ppm and the median was 2.0 ppm. As many plants do not use activated carbon continuously, a more representative figure when odors are present would be 3–4 ppm.

Free Residual Chlorination

Although the principle of free residual chlorination was developed by N. J. Howard (*11*), in Toronto, Ont., in 1929, application in the United States was not adopted until 1939 or 1940. Its acceptance is evidenced by the fact that more than 65 per cent of the reporting plants use or have tried this treatment. Individuals reporting on the questionnaire were requested to limit remarks to influence of the treatment on odors, and results of their replies are also shown in Table 5. It must, therefore, be realized that many plants in the United States utilize this

Degrees of Success With Corrective Treatments, Reported by 241 US Plants *

Super- and Dechlorination (34)						Chlorine Dioxide (70)						Aeration (55)					
Total		Partial		None		Total		Partial		None		Total		Partial		None	
No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
7	24	12	41	10	34	6	13	12	25	30	62	5	11	24	53	16	36
6	30	5	25	9	45	6	14	8	19	28	67	2	6	18	47	18	47
3	17	6	33	9	50	26	49	13	24	14	26	3	14	9	43	9	43
2	20	3	30	5	50	3	14	2	10	16	76	1	7	7	50	6	43
18	23	26	34	33	43	41	25	35	21	88	54	11	9	58	49	49	42

percentage calculations were based on 21, rather than the total 55 reporting that type of odor. Numbers in parentheses after types of treatments represent the total number of plants that tried a specific treatment to combat one or more causes of odor.

treatment for its other advantages, such as better disinfection and improvements in plant operation. Complete success in reducing odors to palatable levels is reported by 28 per cent or less. Best results appear to be obtained with the sewage and sulfide odors, reported in the unclassified grouping, Table 1.

Reports on the merit of free residual chlorination were quite varied, and sometimes difficult to classify. Those recorded as partially successful reported as follows: [1] odor reduced but not to palatable levels; [2] odor sometimes removed but not always; and [3] odor sometimes reduced, other times intensified.

Most of those reporting partial success are practicing free residual chlorination predominantly for its other merits, but also take advantage of what it can accomplish for odor improvement. A few plants report discontinuing free residual chlorination when the odor is intensified.

The majority of those reporting unsuccessful results have discontinued this treatment, although a few practice free residual chlorination in the treatment plant, and then convert to a combined residual by adding ammonia before delivery to the distribution system.

Other Methods

Only 34 plants reported using or having tried super chlorination, so caution should be used in drawing conclusions. Percentage calculations would indicate slightly better success with super chlorination than was reported for free residual chlorination.

The use of chlorine dioxide was first employed in the water field in the United States in 1944, and is formed in the treatment plant by reaction of chlorine and sodium chlorite. The summary in Table 5 indicates limited success with this treatment except on odors of trade waste origin, most of which were phenolic in nature, on which 49 per cent reported complete success. Rarely did any reports indicate lack of success on phenol or phenolic-type compounds, so chlorine dioxide can be considered particularly useful in handling such odors.

Less than 25 per cent of those returning questionnaires reported using aeration. A minor percentage recorded complete success, and it is prob-

able that in such instances the odor concentration was usually at low levels. The general view is that aeration will reduce odor concentrations by only 10–20 per cent, unless they are extremely volatile, such as hydrogen sulfide and sewage-type odors. In one case high-pressure aeration was very helpful in accomplishing a reduction of odors due to trade wastes.

Although ozone was listed in the questionnaire, only 8 plants reported using or having tried this treatment, so it would be unfair to draw conclusions from such a limited number.

A few plants reported employing marginal chlorination for odor improvement, and a somewhat larger number mentioned the use of copper sulfate for control of algal odors. Two plants reported shutting down their operations during odor surges.

Thirty-four plants volunteered the information that chlorine-ammonia treatment is employed, sometimes only as a post treatment, yet in other cases combined chlorine residuals are carried throughout the entire treatment plant and distribution system. Questionnaire responses would indicate that chlorine-ammonia treatment has definite merit as an aid toward delivery of palatable water, and several plants reported utilizing it to eliminate instances of chlorinous, nitrogen trichloride, or chlorophenol odors.

Conclusions

Although great strides have been made within the United States in the production of consistently palatable water, many communities are failing in their obligation to their consumers.

Algae are the most frequent cause of odors in water supplies, with decaying vegetation a close second. Trade wastes, although they occur less frequently, can be much more troublesome.

Algae types most frequently causing odor problems are *Anabaena, Aphanizomenon, Asterionella, Diatoma, Dinobryon, Synedra, Synura,* and *Tabellaria.*

Tastes and odors due to dissolved minerals from underground strata constitute no problem except in certain localized areas. In surface waters the predominant problem is odor rather than taste.

Chlorinous odors continue to be a serious issue, and return to the use of chlorine-ammonia treatment for improvement of water palatability appears to be a growing trend.

Greater importance of palatability is demonstrated by the wider adoption of the threshold dilution procedure for odor evaluation.

Preventive measures, except for control of algae with copper sulfate, are employed very infrequently.

Reports of completely successful corrective treatments show activated carbon far in the lead with an overall effectiveness of 86 per cent compared with 25 per cent for chlorine dioxide, 23 per cent for super- and dechlorination, 17 per cent for free residual chlorination, and 9 per cent for aeration.

The proper point of carbon application in relation to chlorine and pH adjustment chemicals is deserving of further attention in water treatment practices.

From the viewpoint of public health and consumer relationship, water palatability has great significance, and the delivery of a consistently palatable water at all times should be the goal of all progressive individuals in the water works profession.

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Progress Toward AWWA Certification Program

In the description of the proposed AWWA certification program in the August 1957 issue of *Willing Water* (No. 47), it was indicated that members would be kept informed of progress. Although final action is not contemplated until the Board of Directors has had an opportunity to discuss the latest recommendations for the program at its annual meeting in January 1958, definite progress has been made: legal studies of the various alternatives have been completed and the officers and directors are now giving intensive study to the practical administrative features of the program. To clarify the status of the matter at the present time, however, the Executive Committee wishes to emphasize that *to date no AWWA certification program has been adopted.*

Survey of Water Purification Practice in Canada

DeLoss H. Matheson and A. V. Forde

A paper presented on June 19, 1957, at the Canadian Section Meeting, Winnipeg, Man., by DeLoss H. Matheson, Director, and A. V. Forde, Chemist, both of Municipal Labs., Hamilton, Ont.

THE purpose of this article is to present the experience of water purification plant operators in Canada in a form that will provide at least some suggestions for future development. Specifically, this article was prepared to survey the methods of water purification used in Canada and to evaluate their effectiveness. Thus, it supplements the article by Berry and Galimberti in 1954 *(1)*, which surveyed the equipment and design factors in Canadian water treatment plants.

Questionnaires were sent to over 220 water treatment plants in municipalities of over 1,000 population where more extensive treatment than simple chlorination was practiced. Replies were received from somewhat less than one-half of the questionnaires. Most of the municipalities not replying were the smaller ones of population less than 10,000, and they may well have thought that the experiences of their small operations were not significant. These smaller water works frequently have little or nothing in the nature of instruments or test equipment; the plant equipment is installed by others, and the operation is by rule of thumb, directed as required in emergencies by provincial health departments. Nevertheless, it is worth noting that in some of these smaller plants the most enterprising operators have been found who, with limited opportunities and facilities, have had the courage and resourcefulness to tackle problems and to experiment with radical treatments. Manufacturers and suppliers cooperate to a high degree and in a most useful way in providing technical direction in the installation and operation of new processes. Small water works have one additional advantage, in that they can conduct plant scale experiments at a reasonable cost, which cannot be done so readily in large works.

This article is not concerned with a survey of plant equipment, but the facilities available in each case have been considered in connection with the treatment processes.

Coagulation

The importance of the proper preparation of water before filtration is gaining in appreciation. A large portion of the turbidity and color can thus be removed by efficient coagulation and sedimentation, leaving only a relatively small portion to be removed by the filters.

Alum is by far the most extensively used coagulant. Only four plants reported the use of other materials. Sodium aluminate is used at Saskatoon, Sask., and Taber, Alta., and sodium aluminate with alum is used at Picton, Ont., and Malartic, Que. At the latter

plant 35.8 ppm of alum and 3.6 ppm of sodium aluminate produced better coagulation than a larger dose of alum alone. One municipality which did not report in this survey is said to be using an aluminoferric compound.

Liquid alum is now being used in a few plants where it offers certain advantages. The fact that it contains only about 50 per cent as much aluminum oxide as solid alum restricts its use to points within economical hauling distance of the manufacturing plant. The cost of installing corrosion-resistant storage tanks and piping is a considerable item in considering its usefulness. Against this may be offset the fact that it is cleaner to use, it requires no unloading and subsequent handling on the part of the water plant operator, and it is readily fed to the water by orifices, rotameters, or metering pumps. At Welland, Ont., which is very near the manufacturing plant, there is a substantial saving in the cost per ton on the dry-weight basis. The largest user will probably be the Brantford, Ont., water works where it is being installed at present. Toronto Township, on Lake Ontario, is also seriously considering its use.

The dosage of alum used varies over a very wide range, from a very few parts per million to a high of 170 ppm in very turbid waters at Lethbridge, Alta. In most cases the optimum dosages appear to have been determined on the basis of plant experience, although seven plants report using jar tests for this purpose.

A number of plants, including the largest ones, dispense with the use of alum during periods when the raw water turbidity is low. It has been found that the filters, without coagulant, are able to handle low turbidities and produce filtered water of acceptable quality, effecting not only a saving in alum cost, but also avoiding the difficulty of greatly shortened filter runs due to the poor flocculation which occurs in clear waters. This practice is followed at the large filter plants in metropolitan Toronto, and has been used for 20 years at the Hamilton filtration plant. For many years alum application was started at Hamilton when the turbidity reached 10 units; lately it has been started at a turbidity of 5 units to improve the quality of the filtered water. Other plants report that alum is not used until the turbidity reaches 20, and at Montreal, where the maximum turbidity is about 20, no alum is used at all.

At Windsor, Ont., a period of low turbidity resulting in poor coagulation is experienced in spring and fall. Mechanical mixers have been advantageous in promoting floc formation, and it has been found that when the basins are partially filled with sludge a heavier floc is obtained with reasonable alum dosages.

Alum dosages are generally proportioned in some way to the turbidity or color of the raw water. For example, at Lethbridge where a wide range of turbidity occurs, alum is applied at the rate of 14 ppm for each 100 ppm of turbidity, up to a maximum of 170 ppm. In other cities where lower turbidities prevail, treatment may begin at less than 14 ppm.

In many smaller municipalities no equipment is provided for measuring turbidity or color, and the coagulant dose is maintained at a constant rate, or is adjusted by visual observation of the appearance of the incoming water.

At Brantford, Ont., and a few smaller works the appearance and settling properties of the floc itself are used directly to determine the coagulant

dose. In only one case (Windsor, Ont.) was it reported that the turbidity of the filtered water was used directly as a control factor.

Turbidity and color-measuring devices which have been mentioned range from the simplest visual means to automatic recording equipment. Four plants, including metropolitan Toronto's large plants, rely on bottled turbidity standards. Four plants use candle turbidimeters, one plant uses the platinum wire method, and two others use visual or photoelectric colorimeters.

At Hamilton, Ont., a continuously recording photoelectric turbidimeter has been used on the raw water for several years, and at Edmonton, Alta., recording turbidimeters are being installed. In view of the fact that there are available a number of turbidity measuring instruments which are inexpensive and easy to use, it is surprising that so many plants have to operate without their aid.

Measurement of the turbidity of filtered water is a more difficult matter, and is regularly performed at only a few plants. The instruments used are visual and photoelectric turbidimeters and bottled standards.

Coagulant Aids

In line with the increasing importance attached to water preparation before filtration a number of methods of improving coagulation have become available in the last few years. These aids act in two different ways: by increasing the strength of the floc, and by causing it to settle more readily. There are applications in many plants of these methods, and others have them under study.

Prechlorination was advocated for improving coagulation many years ago, but in this survey only four plants reported its use primarily for this purpose. At Brantford, Ont., laboratory and plant tests showed that prechlorination did not aid coagulation, but a high level of free residual prechlorination decidedly aids in maintaining filters in a desirably clean condition. Other plants use prechlorination for other reasons, but indicate that some improvement in coagulation also results. In plants where severe difficulties due to algae are experienced, heavy prechlorination undoubtedly improves the coagulation and sedimentation of these organisms.

The use of the addition of clay to aid in flocculation of clear waters and to promote sedimentation by weighting the floc has been reported upon very favorably in several American plants, but in this survey only two plants mentioned its use. At Melartic, Que., two types of clay were used in a precipitator without producing sufficient improvement to justify the high cost. At Brandon, Man., clay is used during periods of low temperature and low turbidities to hold the floc down in a suspended-solids contact basin. It has definitely proved beneficial when used in large enough quantities (12 ppm or more). The clay is gathered locally, the material which creates the highest turbidity being chosen. At Kingston, Ont., the use of bentonite clay is now contemplated.

The use of activated-silica sols at dosages of 3–10 ppm is valuable in producing a heavier, tougher, and better settling floc, and is used or planned in nine reporting Canadian plants. It is known that in some cases its use results in shortened filter runs, but none of the plants presently using the process has commented on this aspect of the treatment, although this effect may have occurred to some degree.

Almost every possible activating agent is represented in the plants which use silica sols. At Smith Falls, Ont., silica is activated by alum, and is used seasonally during periods of high color and low temperature. At Brandon, Man., chlorine-activated silica has been used continuously for about 1 year with satisfactory results. Its use permitted an increase in the flow through the solids contact basin and allowed some reduction in alum dosage at higher water temperatures. At Brantford, Ont., silica activated with chlorine has been proved advantageous on a laboratory scale, and plant use is anticipated. At Malartic, Que., silica activated by ammonium sulfate gave good results in plant use some years ago, but resulted in shortened filter runs. Its use was discontinued due to other plant changes, but is being reconsidered now. At the Moose Jaw, Regina, Sask., plant, silica activated by sulfuric acid is used continuously. At Dundas, Ont., silica activated by sodium bicarbonate is used in coagulating a colored water, and by greatly improving coagulation it permits the operation of the plant at much above rated capacity.

There are certain proprietary organic materials available now, which hold considerable promise in improving water coagulation. They are widely used in industrial water and waste treatment processes to aid flocculation, and their effect is quite striking. Although they are said to have passed toxicity tests, their use in potable waters has not received state- or provincewide approval; the one plant-scale test in Canada was permitted by special arrangement with the Quebec Department of Health.

At Malartic, Que., jar tests indicated that 1–2 ppm of a coagulant aid in addition to the existing treatment would improve floc size, settling rate, and color removal to a high degree. Plant-scale experiments were not as decisive as the jar tests in respect to settling rates, but this may have been due to the differences in mixing. The improvement in color removal, however, was especially noticeable.

At Wainwright, Alta., and at Hamilton, Ont., jar tests have been mentioned, using two other coagulant aids. These substances are quite expensive at the present time, and the desirability of using them in potable water is questionable,* but they constitute a most interesting field for experimentation.

Algae Control

The presence of large growths of algae in raw-water supplies profoundly affects the operation of filtration plants. Where the supply is from a relatively small body of water—a small lake or impoundment—control of algae growth by the use of algicides is practicable. At Dundas, Ont., copper sulfate is applied at frequent intervals to the water above a dam, to stop the growth of algae. At the Moose Jaw-Regina Sask., plant it has been proposed to use a copper citrate preparation from which insoluble copper carbonate does not precipitate as quickly as it does from copper sulfate. At Chatham, Ont., open settling basins are treated with copper sulfate.

Once the algae-containing water has entered the treatment plant there is little that can be done to reduce the effect of algae on filtration. Heavy

* The USPHS has established a Technical Advisory Committee on Coagulant Aids for Water Treatment to review and analyze information on the composition and toxicity of such materials and to advise on their safety for use in potable-water treatment. It is suggested that no material be used that has not been cleared by action of the committee.—Ed.

prechlorination is of value in some cases, depending on the specific organisms concerned. Copper sulfate treatment in the plant is of little value, as experiments at Hamilton have shown, but at Weyburn, Sask., its use is reported to have given satisfactory results.

A new method of dealing with the problem of algae in water—the removal of the organisms by microscreening—is attracting considerable interest at the present time. Extensive experiments with a pilot microscreening plant have been carried out at Belleville, Ont., where the algae problem is especially severe (*2*). Plankton removal was very high (95–99 per cent) and all organisms, even the soft-bodied ones, were removed equally well. Microscreening before conventional treatment would have the advantage of removing most of the filter blocking organisms, reducing chlorine demand by removing a large proportion of the organic matter, and it could make considerable improvement in taste and odor where these are caused by the action of chlorine on the algae. Microscreening also has a field of usefulness as the sole treatment by removing algae from clear waters which do not require filtration. In addition to the test at Belleville, microscreening tests are planned or in progress at several other Ontario points including Peterborough. At Brockville a full-scale installation is being planned as the only treatment preceding chlorination.

Contact Basins

Suspended-solids contact basins of a number of different manufacturers have been installed in many newly constructed plants. The operation of these devices appears to be quite satisfactory on the whole, the greatest difficulties apparently arising from the poorer flocculation that occurs at low water temperatures.

At Brandon, Man., the capacity is reduced to about one-half of normal rating during the period of low temperature, and clay is used to hold the floc down. At the Moose Jaw-Regina, Sask., plant plankton organisms are not removed, and carry over to the filters. At Port Credit, Ont., the operation has been upset as a result of fluctuations in flow.

Color Removal

Treatment for the removal of color is required at seventeen plants reporting. In some places the color is a seasonal problem, but in most it is continuous. The highest values for color were reported at Edmonton, Alta. (360), followed by Iroquois Falls, Ont., and Malartic, Que. (250). In most cases the color arises from swamps and muskeg areas on the watersheds.

Color removal is effected by alum coagulation at a low pH (5.0–6.0), which is obtained by using a large dose of alum. Alum dosages are thus frequently proportioned against raw-water alkalinity rather than against color intensity. Because filtered water at this low pH is corrosive, adjustment of the pH to a higher value is required, and this is effected by the addition of lime or soda ash.

It is noteworthy that the only interference with color removal which was mentioned was at Ottawa, Ont., where it is attributed to the intermittent occurrence from natural sources of small amounts of fluoride in the river water.

Filtration

Rapid gravity filters are the ones most generally used for filtration, fol-

lowed by pressure filters. It is worth noting that there are still in use in Canada a number of slow sand filters (five in Ontario, eight in Quebec, one in Nova Scotia) and three drifting sand plants (Brampton, Rockland and Toronto, Ont.).

The Toronto plants are the only ones which are well documented. The slow sand filters operating at 0.03–0.05 gpm per square foot handle raw water whose turbidity ranges from 1 to 800, without the use of coagulant. They are scraped every 2 weeks and raked once in the interval. They have operated without major repairs since their installation in 1911. The drifting sand plant, installed in 1918, operates at 2.5 gpm per square foot, using the same raw water and alum at doses from zero to 35.8 ppm. In both cases the quality of the filtrate is excellent.

The details of filter design will not be discussed, except to note the increasing importance which is attached to the use of surface wash in keeping the filters clean. In two large plants at Toronto and Hamilton, where surface wash is not installed at present, new filters being constructed will include this feature.

The maximum length of filter run is usually set at 24 hr; a few plants run longer, and some terminate runs at 18 hr. Since wash water is usually not an expensive item in filtration plants, the use of more frequent washes to keep the filters clean is economical and efficient. The length of run, if not limited by the maximum mentioned, is usually determined by the loss of head. At Ottawa, Ont., the appearance of color in the filtered water terminates the run.

Difficulties experienced in filter operation do not appear to be serious. Only one plant mentioned the presence of mudballs, and one plant reported difficulty with air binding during periods of high water temperature. The interference of algae on filter runs is sometimes combated by using a very short wash or bumping of filters between regular washes, to break up the mat of algae on the sand surface. This practice, which was used at Hamilton for a number of years, was discontinued because of the deterioration in quality of the filtered water following bumping.

Disinfection

Chlorine is used almost exclusively for disinfection; only one plant in Canada uses ozone. Chlorination is so inextricably involved with the control of taste and odor that it is difficult to separate the two. Free chlorine is most generally used, as distinguished from the intentional use of combined chlorine, but it is by no means certain that the residual obtained is always free chlorine.

Combined-chlorine residuals are maintained at four larger municipalities (Brantford and Hamilton, Ont., Victoria, B.C., and Winnipeg, Man.) and several smaller places. The reasons for choosing this combined residual are the more stable residual which persists throughout the distribution system, the avoiding of chlorinous odors in the presence of organic matter, and the avoiding of chlorophenolic odors.

The measurement of chlorine residual is usually done by the orthotolidine method, using bottled standards or permanent glass standards. The increasing application of residual recorders is of considerable interest. There are now twenty units in operation: nine in Ontario, one in Saskatchewan, one in Alberta, one in British Columbia, five in Quebec, and three in New Brunswick.

Tastes and Odors

Taste and odor difficulties are widespread in water purification. More than 50 per cent of the plants which reported in this survey employed some treatment specifically for taste and odor improvement. The objectionable taste and odors arise from algae, decomposing vegetable matter in swamps and muskeg, and phenolic substances in industrial wastes. Taste and odor from the first two sources frequently occur in the same water supply, and are usually increased in intensity by chlorination at low dosages. In the third case the objectionable taste and odor arises directly from chlorination.

Five municipalities use chlorine-ammonia treatment instead of chlorination to avoid the production of taste and odor. This treatment is effective since it reduces the chemical reactivity of chlorine and thus prevents the reaction of chlorine with organic substances. At Edmonton and Calgary, Alta., and Victoria, B.C., chlorine-ammonia treatment is used continuously to prevent the development of chlorinous odors when algae are present. At Welland and Hamilton, Ont., chlorine-ammonia treatment is used to avoid the development of chlorophenolic odors. Since the occurrence of phenolic substances is intermittent and unpredictable, this treatment must be used continuously. At Welland chlorine dioxide treatment is available if needed for abnormally high phenolic concentrations, but at Hamilton the chlorine-ammonia treatment has been entirely satisfactory in handling any concentrations of phenol which have occurred to date.

High dosages of chlorine may frequently be effective in controlling taste and odor by the chemical destruction of organic matter by a free chlorine residual. This involves the use of quite high chlorine dosages to maintain high residuals, and when the operation is well controlled the results are highly satisfactory.

At Windsor, Ont., where algae and industrial wastes combine to make a difficult problem the maintenance of high free chlorine residuals, and careful control of the treatment has been extremely effective. Tests are made every hour for taste and odor and chlorine demand. When taste and odor are encountered tests are made at several points at more frequent intervals, and free chlorine residuals are maintained at not less than 0.6 ppm.

Superchlorination as developed by the late N. J. Howard is used at the two large Toronto plants for the control of taste and odor from phenolic wastes and is very effective.

At Brantford, Ont., the extremely polluted Grand River water is treated by heavy chlorination to give a free chlorine residual of 2.5–4.5 ppm after 1 hr contact, then dechlorinated by sulfur dioxide, and finally given a chlorine-ammonia treatment to carry a residual through the distribution system. The details of this highly specialized problem have been published in several articles (*3–6*).

Less extreme chlorine treatment has been reported by some municipalities as giving satisfactory results under their circumstances. At Ottawa, Ont., with a soft, colored water, no other taste and odor treatment has been required since prechlorination has been used. At Chatham, Ont., fairly good control of taste and odor from algae results from prechlorination, and at Shawinigan Falls, Que., high prechlorine treatment for algae odors is effective.

Prechlorination has another valuable effect in taste and odor control by retarding the decomposition of sludge in settling basins and thus preventing the development of putrefactive odors.

Chlorine dioxide is effective, convenient, and economical for the destruction of chlorophenolic odors, and facilities for its use are provided in several plants, all in southern Ontario (Scarborough, New Toronto, Port Credit, Toronto Township, Welland, Thorold, Dundas, and Perth). In some, the treatment is used only when it is required, with the result that some odorous water is delivered to the distribution system before the treatment can be started. In others the treatment is maintained continuously at a low rate to take care of the erratic occurrence of phenolic contamination. At Perth, Ont., the use of chlorine dioxide for algae odors is reported as satisfactory, and at Dundas chlorine dioxide prevents the development of chlorinous odors on treating a highly organic water.

Activated carbon does not appear to be widely used for taste and odor control. At the Regina plant it is used with prechlorination with good results for odors from algae and decaying vegetable matter. At Edmonton, Alta., dosages of carbon up to 40 ppm are required for effective taste and odor removal during the spring breakup. Dosages up to 12.5 ppm were ineffective. The use of carbon slurry is being considered. At Wainwright, Alta., heavy prechlorination of a highly organic water produced chlorinous odors which could be removed by feeding a large dose of carbon directly to the filters. A continuous dose of 3 ppm activated carbon is also used the year round. At Dundas, Ont., carbon is used when abnormally high odors are not removed by other treatment.

Hydrogen sulfide odors in well waters are generally susceptible to removal by aeration as at Virden, Man., and London, Ont. At Watford, Ont., high chlorination following aeration is necessary.

Softening

There are nine softening plants in Canada using the lime or lime–soda process, of which only four (Edmonton and Wainwright, Alta., Brandon and Boessevain, Man.) contributed to this survey. They soften raw waters with hardness varying from 100–600 ppm down to 75–125 ppm; recarbonation to stabilize the softened water is practiced in all. At Brandon, Man., polyphosphate at 1 ppm is also applied to stabilize the water in the distribution system.

In metropolitan Toronto, there are six small plants softening well waters by resin ion exchanger. The hardness is reduced from 300–500 ppm to 125 ppm. In four plants aeration and filtration is provided for iron removal; in the other two the iron is removed by the ion exchanger.

There are some nine or ten other municipalities in Canada which remove iron from well water supplies by aeration and filtration.

Conclusion

Water treatment in some 200 plants in Canada which employ more extensive treatment than simple chlorination appear to be effectively and efficiently conducted. A wide variety of water conditions exist, and almost all practicable water treatment processes are represented in the water works which have been surveyed. Where treatment in its present form is not adequate, improved processes are being studied, planned, or installed. It is noted that in some of the smaller works the opera-

tors show interest and enterprise in investigating the possibility of finding solutions to their problems.

One question asked in the survey—"Do you have any problems that are not handled by known methods of water treatment?"—brought a practically unanimous answer in the negative.

The authors are much indebted to the many water works engineers throughout Canada who kindly contributed the data for this paper.

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Acceptability of Membrane Filter Procedure

The Executive Committee of the AWWA Board of Directors, on Nov. 7, 1957, adopted the following resolution:

Whereas the current (tenth) edition (1955) of *Standard Methods for the Examination of Water, Sewage, and Industrial Wastes* includes the membrane filter procedure as a *tentative* method for the determination of the presence of members of the coliform group, and

Whereas the US Public Health Service has, by official action, taken on Mar. 1, 1957, accepted the membrane filter as an alternate to the completed test for members of the coliform group,

Therefore, be it resolved that the American Water Works Association accepts the membrane filter procedure as an alternate to the completed test when the following conditions have been met:

a. The administrator of the laboratory concerned has satisfied himself by comparison tests that the membrane filter procedure produces results which are essentially equal to the completed test, and

b. The state sanitary engineering laboratory approves the application of the membrane filter procedure to the public water supplies under its jurisdiction.

A Statistical Analysis of Water Works Data for 1955

Harris F. Seidel and E. Robert Baumann

A contribution to the Journal by Harris F. Seidel, Supt., Water & Sewage Treatment, Ames, Iowa, and E. Robert Baumann, Prof. of Civil (San.) Eng., Iowa State College, Ames, Iowa.

In May 1957 the JOURNAL published "A Survey of Operating Data for Water Works in 1955" (*1*)—perhaps one of the most formidable and impressive masses of numbers published recently by a nongovernmental organization. The survey comprised a wealth of information on physical systems, water use, rates, and finances of 497 United States water utilities serving populations of 10,000 or more. The combined population served by these utilities was just over 70,000,000—more than 60 per cent of the total population served by all water utilities.

The data present at least two broad areas of interest which are open to a statistical approach. The first involves the presence (or absence) of general trends, as shown by averages, ranges, and frequencies, which may answer such questions as: Is a specific cost element affected by size of city? Do high rates affect water use? Are rates keeping up with rising costs? What can be learned from a comparison of the current survey with the surveys of 1950 (*2*) and 1945 (*3*)?

The second area of interest is the possibility of determining norms or typical data for various aspects of water works operation so that the management of a particular utility can judge how it compares with other utilities operating under similar conditions.

Statistical Terminology

The statistical methods used in this study were relatively simple, and the terminology is correspondingly simple. An analysis of rates charged for the first 1,000 cu ft of water used per month will serve as an example (Fig. 1).

This item was reported by 480 cities; the charges ranged from \$0.68 to \$7.50. Summing all charges and dividing this total by the number of cities reporting yielded the arithmetical average or *mean* value (black triangle) of \$2.75. All mean values are unweighted; no extra weight was given data from the larger cities, as the main object of this analysis was to arrive at values most representative of the largest number of water utilities.

The mean value, while familiar to all, may be appreciably distorted by a few unusually high or low values. Consequently, the *median* value (white triangle) is generally a better indication of the most common or typical value in a group of data; it is the midpoint of the series, with as many individual values above as below it in the range of the series.*

* In the discussion which follows, averages of mean and median values are sometimes used, when such averages were considered to be more typical than either mean or median values.

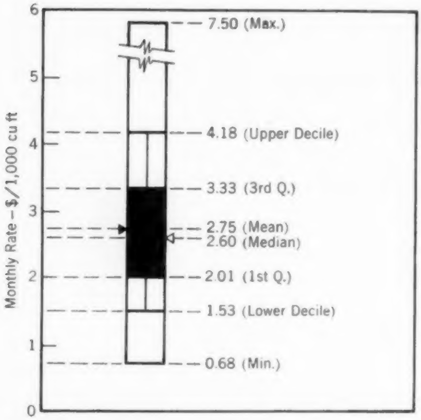

Fig. 1. Monthly Rates for First 1,000 cu ft

These data are based on returns from 480 cities.

The *quartiles* provide further information on grouping. A quarter of the values lie below the first quartile value and a quarter above the third quartile. In these terms, half the rates in Fig. 1 lie between \$2.01 (1st Q.) and \$3.33 (3rd Q.), which is less than one-fifth the full range (\$0.68–\$7.50) for the group. The second quartile value is, of course, the median.

The *decile* values merely carry this bracketing one step further in an effort to discount the undue influence of unusually low or high values on the plotted range. In Fig. 1, only one-tenth of the data lie below \$1.53 (lower decile) or above \$4.18 (upper decile); thus, 80 per cent of the data lie within these limits, which comprise less than 40 per cent of the overall range of the data.

With this information plotted in a summary bar graph such as Fig. 1, the general pattern of 1,000-cu ft rates is apparent at a glance, as well as the quartile in which a specific rate falls, or whether it happens to be in the lower or higher tenth of all those reporting.

A statistical pattern may also be plotted in the form of a frequency distribution. The vertical bars in Fig. 2, for example, indicate the number of cities that reported per capita production values falling within the steps shown by the bottom scale. It is noteworthy that, despite mean and median production values of 137 and 122 gpcd, respectively, the heaviest concentration of data still falls around the 100-gpcd value. The summary bar graph and frequency distribution can be used together, as shown.

Limitations

It is well said that statistics can be used to prove almost anything. Consequently, part of the job of presentation is to define properly the limits and characteristics of the data.

For example, the mean monthly charge per 1,000 cu ft for 480 cities was found to be \$2.75. A second

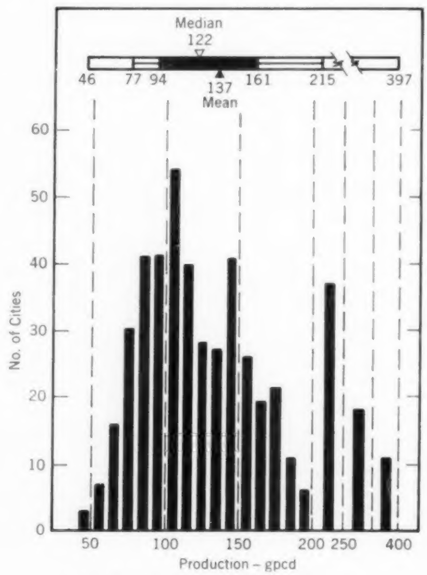

Fig. 2. Per Capita Production

This frequency distribution is based on returns from 477 cities. Per capita figures refer to total (retail plus wholesale) population served.

look, however, indicates that the mean rate for publicly owned utilities is $2.62, compared to $3.70 for those privately owned; lower production volume, a heavy tax load, and the profit motive are jointly responsible for the higher rate schedules of private utilities.

about $2 for the largest cities. When arranged in groups according to volume of water produced, the rate variation from smallest to largest producers is even greater.

Another important factor influencing water rates is the type of treatment;

Concordance of Survey and Analysis Tables

Survey (May 1957 Journal)	Subject	Analysis (Dec. 1957 Journal)
Table 1, Column		Table (T) or Figure (F) No.
1	Population & volume groups	T1
16	Distribution storage	T9
17–20	Distribution pressure	T11
21, 22	Distribution temperature	T10
Table 2, Column		
6	Distribution mains	T8
8	Valves	T9
10	Hydrants	T9
15	Unaccounted-for water	T5
16	Per capita production	T2, T3, F2, F3
17	Per capita distribution	T4
Table 3, Column		
2	Employees	T12
3–7	Customers	T13, T14
—	Customer water use	T6, T7, F4
8, 9	Services metered	T15
10	Billing period	T16
11, 13	Minimum charge & allowance	T17
Table 3, Column		Table (T) or Figure (F) No.
14–17	Monthly rates	T20, F1, F12
—	Effect of rates on use	F5
—	Rates & treatment type	F6
18	Hydrant charge	T18
20	Billing written off	T19
Table 4, Column		
2–4	Sources of revenue	T22, T31, F8, F9
11	Per capita revenue	T21, F7
13, 14	Operation & maintenance	T23
18	Per capita expense	T24
20–24	Funds for capital additions	T28
25, 26	Book value	T29, T30
27–29	Reserves & debt	T29, F11
31	Earnings	T25
32–39	Disposition of earnings	T26, T27, T31, F10
	Comparisons	
—	Public & private	T32, T33, F12–F14
—	1945–55 data	T33, F13, F14

Are there other factors which affect rates? Further analysis by size of city indicates that the mean monthly rate per 1,000 cu ft for publicly owned utilities varies from roughly $3 in the 10,000–25,000 population bracket to

utilities needing only to chlorinate and distribute a well supply can operate at a considerable advantage in costs and rates over those required to treat a surface supply. Rates can also be shown to vary with geographic area.

It is apparent that a completely fair comparison of water rates should consider ownership, population, volume, treatment, and location (not to mention source, climate, and other factors), but this makes the comparison too complicated to be of any practical value. The major factors affecting any item must be taken into account, however, if a statistical analysis of the data is to have meaning.

The second important limitation in statistical work is the "sample" itself. The mean monthly rate per 1,000 cu ft for publicly owned utilities was stated to be $2.62. This, of course, was the mean *for those reporting.* It is scarcely possible, nor is it necessary, to obtain data from every water utility. Instead, statistical work relies on a partial sample which is presumed to be representative. Thus, statistical results can only be as good as the original sample and the accuracy of reporting—a problem which is not eased by the wildly varying interpretations placed on such terms as "free service," "depreciation," and "earnings." Comparisons of 1955 data with results from the two earlier AWWA surveys are valid only to the extent that the sampling was equally good in all and that terms such as "earnings" were used in like context.

Despite the limitations described, results obtained from each succeeding survey have been increasingly authoritative and of growing value to the water works field. Approximately two-thirds of the cities included in the 1955 survey had also responded to one or both of the previous two.

Scope of Study

The discussion of the statistical material follows generally the organization of the survey (see table on p. 1533). The categories analyzed include: production and distribution; physical system; billing and rates; revenue; expense; comparison of privately and publicly owned utilities; and comparison with statistical analyses of previous surveys (*4, 5*).

For purposes of this analysis, the cities were divided into the following population groups:

Population Group	Population Served at Retail *1,000's*
1	10–25
2	25–50
3	50–100
4	100–250
5	250–500
6	over 500

For many items, a grouping by volume of production yielded more definite trends than an analysis by population groups. For volume groups, the following classification was used:

Volume Group	Production *mgd*
1	under 2
2	2–4
3	4–6
4	6–10
5	10–20
6	20–50
7	over 50

These volume groups do not duplicate those used in the analysis of the 1950 survey (*4*) but are in the more familiar terms of mean daily production. Generally speaking, considerable variation in size of city occurs within a volume group, as indicated in Table 1. Throughout the tables and illustrations, the population and volume groups are referred to by the above numbers.

Production and rates also vary with geographic location; the regional groupings used, as in past surveys, are as follows:

1. *New England*—Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont

2. *Middle Atlantic*—Delaware, Maryland, New Jersey, New York, Pennsylvania; also Washington, D.C.

3. *North East Central*—Illinois, Indiana, Michigan, Ohio, West Virginia

4. *North West Central*—Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota, South Dakota, Wisconsin

5. *South*—Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, Virginia

No attempt was made to summarize the volume of water produced from ground or surface sources and treated by different methods, or the population served by the various combinations of source and treatment. This information was recently accumulated in great detail by the US Public Health Service; a summary by Ralph Porges (*6*) appears in this issue (p. 1567).

Production

Per capita water use has long been a favorite item for comparison. In

TABLE 1

Retail Population of Cities in 1955 Survey, by Volume Groups

Volume Group	No. of Cities	Population—*1,000's*					
		Min.	Max.	Mean	1st Q.	Median	3rd Q.
1	98	10	30	16	13	15	18
2	128	11	60	25	18	23	30
3	64	13	75	37	26	34	50
4	63	21	155	60	44	59	71
5	49	30	210	110	80	104	148
6	54	55	555	223	142	195	283
7	37	165	7,650	1,030	500	585	920
1–7	493	10	7,650	135	20	35	93
1–7 (1950)	386	10	4,138	121	20	38	95

6. *Mountain*—Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah, Wyoming

7. *Pacific Coast*—California, Hawaii, Oregon, Washington.

The type of treatment has a definite bearing on operating costs, and thus on rates. The cities surveyed were classified by treatment type in three groups:

Minor—all cities not falling in another group (majority providing chlorination only)

Filtration—all cities reporting filtration, but not softening

Softening—all cities reporting softening, with or without filtration or other treatment.

the 1955 survey, per capita production was determined by dividing mean daily production by total (retail and wholesale) population served. For the 477 cities reporting these data, mean and median values were 137 and 122 gpcd, respectively, although the range of greatest frequency was 80–120 gpcd (Fig. 2).

Size of city (Table 2), above 10,000 population at least, was found to have little effect on per capita production. The only exception was the group of cities over 1,000,000 in population (part of Population Group 6), for which mean and median production values were in the range of 175 gpcd.

TABLE 2

Production, by Population Groups

Pop. Group	No. of Cities	Production—*gpcd**					
		Min.	Max.	Mean	1st Q.	Median	3rd Q.
1	178	53	333	132	91	114	161
2	111	47	397	143	95	130	177
3	73	46	392	123	89	111	144
4	65	46	392	147	100	131	168
5	20	94	213	142	120	142	157
6	30	78	234	146	112	146	176
1–6	477	46	397	137	94	122	161
1–6 (1950)	387	51	446	138	95	122	160
1–6 (1945)	398	34	546	125	85	110	145

* Per capita figures based on total (retail plus wholesale) population served.

TABLE 3

Production, by Geographic Regions

Region	No. of Cities	Production—*gpcd**					
		Min.	Max.	Mean	1st Q.	Median	3rd Q.
New England	38	59	263	123	92	115	147
Middle Atlantic	73	56	380	139	94	122	173
South	106	46	275	109	84	103	124
N. East Central	84	46	286	130	92	126	152
N. West Central	100	51	295	127	93	117	157
Mountain	17	97	397	220	149	202	248
Pacific Coast	59	85	356	193	143	179	228
US	477	46	397	137	94	122	161

* Per capita figures based on total (retail plus wholesale) population served.

TABLE 4

Distribution, by Population Groups

Pop. Group	No. of Cities	Distribution—*gpcd**					
		Min.	Max.	Mean	1st Q.	Median	3rd Q.
1	136	51	326	118	80	100	139
2	93	37	397	123	77	108	149
3	65	39	392	106	78	92	119
4	54	46	331	124	79	112	145
5	16	87	181	125	102	122	140
6	27	63	230	127	93	122	156
1–6	391	37	397	119	81	104	142

* Per capita figures based on total (retail plus wholesale) population served.

When analyzed by volume groups (Fig. 3), a definite trend was evident. As the total production increased, per capita production also increased fairly consistently, from about 90 gpcd for Volume Group 1 to 160 gpcd for Volume Group 7. This suggests that, as in other industries, the larger water utilities are able to take advantage of lower unit costs to provide water at lower rates and thereby stimulate sales.

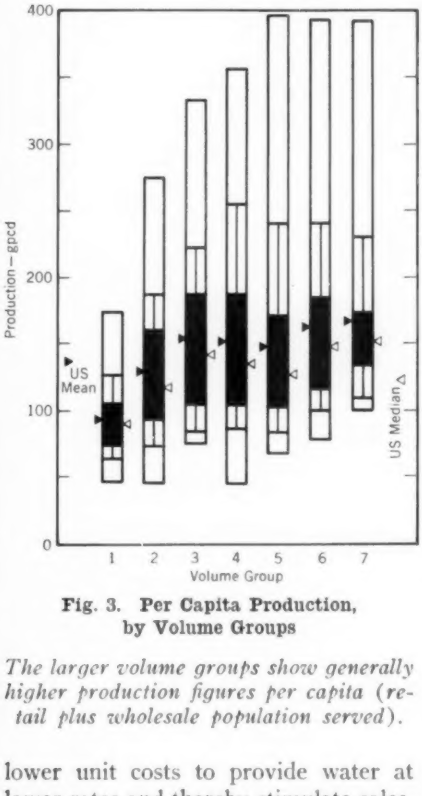

Fig. 3. Per Capita Production, by Volume Groups

The larger volume groups show generally higher production figures per capita (retail plus wholesale population served).

Production also varied with geographic region (Table 3). As in the two previous surveys, per capita water use was considerably higher in Pacific and Mountain states than in other areas. A study of only those cities reporting in both the 1950 and 1955 surveys indicated decreases of 7 and 8 per cent in Pacific and Mountain regions, respectively; increases of 4 per cent in New England and North West Central regions; and negligible changes in other areas over this 5-year period. Possibly regional climatic conditions played as important a part in these variations as any other single factor.

It is of particular interest to note that per capita water use did not change significantly from 1950 to 1955. This is in contrast to a 10 per cent increase during the 1945–50 period. It should be pointed out, however, that the 1950 data did not include population served at wholesale in a number of cases, which may have affected the per capita figures, but not by more than 1–2 gpcd.

TABLE 5

Frequency Data on Percentage of Production Sold and Unaccounted for *

Production Sold *per cent*	No. of Cities	Unaccounted for *per cent*	No. of Cities
100.0	22	0.0	90
95.0–99.9	49	0.1– 4.9	40
90.0–94.9	61	5.0– 9.9	52
85.0–89.9	78	10.0–14.9	72
80.0–84.9	70	15.0–19.9	55
75.0–79.9	51	20.0–24.9	33
70.0–74.9	33	25.0–29.9	17
60.0–69.9	24	30.0–39.9	13
under 60.0	13	40.0 or more	7
Total	401	*Total*	379

* "Production sold" percentages are based on sales reported (Survey Table 2, Col. 12); "unaccounted for" percentages are based on total distribution (sales plus free) reported (Survey Table 2, Col. 14).

Distribution

Many cities reported the volume of water sold and an amount designated as "free service." The sum of sales and free service was tabulated as "total distribution." Approximately 20 cities reported sales as matching production exactly, and about 70 more indicated

that sales plus free service, or total distribution, precisely equaled production. This is an admirable achievement, if accurate, but the statistical results involving such data are suspect. Mean and median values for total distribution were found (Table 4) to be 119 and 104 gpcd, respectively, subject to the reservations noted.

A frequency distribution (Table 5) of data on percentage of production sold and percentage unaccounted for indi-

TABLE 6

Residential Water Use, by Volume Groups

Volume Group	No. of Cities	Annual Use per Residential Service—*1,000 gal*					
		Min.	Max.	Mean	1st Q.	Median	3rd Q.
Publicly Owned Utilities							
1	15	29	101	53	46	50	55
2	20	31	123	64	48	60	70
3	11	38	129	75	55	62	97
4	14	41	151	82	57	80	97
5	8	62	117	81	(65)	77	(92)
6	6	74	103	89	(82)	90	(97)
7	12	62	149	94	72	97	107
1–7	86	29	151	74	53	68	96
Privately Owned Utilities							
1	7	42	58	49		48	
2	8	34	96	55		45	
3–7	10	49	118	71		70	
1–7	25	34	118	60	45	52	75

TABLE 7

Customer Water Use

Customer Class	No. of Cities	Annual Use per Service—*1,000 gal*					
		Min.	Max.	Mean	1st Q.	Median	3rd Q.
Publicly Owned Utilities							
Residential	86	29	151	74	53	68	96
Commercial	68	120	880	390	250	350	450
Industrial	66	400	54,500	10,000	4,100	8,000	13,300
Privately Owned Utilities							
Residential	25	34	118	60	45	52	75
Commercial	23	120	640	300	170	280	370
Industrial	21	400	54,000	7,000	2,100	3,600	6,300

cated the ranges of most common experience to have been 80–95 per cent sold and 5–20 per cent unaccounted for (disregarding those cities reporting 100 per cent distribution). Highest frequency of occurrence was noted for values of 86 per cent and 12 per cent, respectively; this was not significantly better or worse than in the two previous surveys.

The survey tabulation also included data on loss per mile of main, assuming all undistributed water to be lost via distribution mains. In those terms, the most representative values were in the range of 4,000–8,000-gpd loss per mile.

Water Use

After the original survey data had been received and tabulated, a second request was sent to 150 utilities for more detailed information on water sales. From this mailing more than 125 replies were received, most of them quite complete.

From the breakdown of water sales into residential, commercial, and industrial categories, and from data previously furnished (Survey Table 3) on the number of services in each class, mean annual water use per service was calculated.

Mean residential water use (Table 6) was found to vary from about 50,000 gal per service per year (approximately 140 gpd) for the smaller utilities to 100,000 gal per year (roughly 275 gpd) for cities in the largest volume group. For privately owned utilities, a parallel trend was observed, but with the water use per service generally 10–20 per cent lower than for publicly owned utilities.

For commercial and industrial use, similar trends were lacking. The variations in mean use per service were greater, however, particularly for the industrial class. In very general terms, commercial use was reported most commonly to be in the range of 0.25–0.5 mil gal per service per year, while industrial use ranged most frequently from 3 to 12 mil gal. For privately owned utilities, commercial and industrial use per service was roughly 20 per cent and 35 per cent less, respectively, than for publicly owned utilities. Table 7 summarizes water use data for all three service classes.

Analysis of the sales breakdown itself, in terms of total volume for these three classes only (Fig. 4), was also

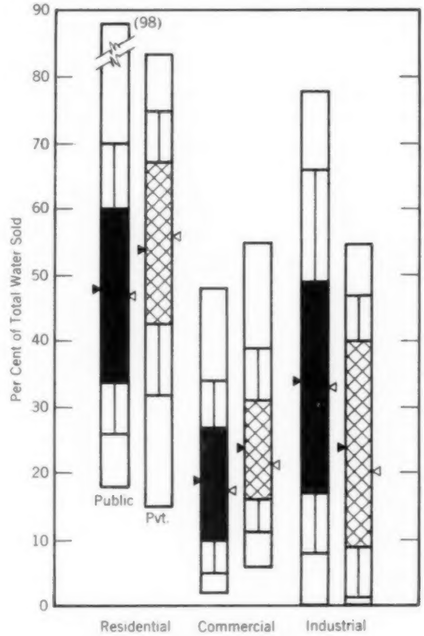

Fig. 4. Breakdown of Sales by Service Classes

"Total water sold" refers to total sales to residential, commercial, and industrial accounts (municipal sales and free service excluded). The left-hand bar of each pair shows data for publicly owned utilities, the right-hand for privately owned.

productive. For publicly owned utilities, commercial sales increased (from 17 to 25 per cent) and industrial sales decreased mildly (from 35 to 30 per cent) in importance from the smallest to the largest population group. Residential sales accounted for half or slightly more than half of total sales in cities of 50,000–250,000 population, and less than half in cities smaller and larger than this.

For privately owned utilities, the im-

TABLE 8

Distribution Main Mileage, by Population Groups

Pop. Group	No. of Cities	Miles of Main per 1,000 Retail Pop.					
		Min.	Max.	Mean	1st Q.	Median	3rd Q.
1	147	0.8	5.3	2.9	2.3	2.8	3.5
2	104	0.9	4.7	2.6	2.2	2.7	2.9
3	70	0.7	4.9	2.4	1.8	2.4	2.8
4	57	0.9	4.6	2.4	2.0	2.3	2.6
5	20	1.1	3.1	2.1	1.6	2.1	2.6
6	25	1.2	3.2	2.0	1.5	1.9	2.3
1–6*	423	0.7	5.3	2.6	2.0	2.5	3.0
1–6 (1950)†	386	0.5	5.9	2.4	1.9	2.3	2.7
1–6 (1945)*	418	0.2	8.4	2.7	2.0	2.5	3.1

* Based on actual mileage of all sizes of mains.
† Based on miles of 8-in. equivalent main.

TABLE 9

Frequency Data on Valves, Hydrants, and Storage

Valves		Hydrants		Distribution Storage		
Per Mile of Main	No. of Cities	Per Mile of Main	No. of Cities	Days*	No. of Cities: Publicly Owned	No. of Cities: Privately Owned
1.6– 3.9	6	1.4– 2.9	6	0.0– 0.2	18	4
4.0– 5.9	14	3.0– 3.9	19	0.2– 0.4	57	15
6.0– 7.9	31	4.0– 4.9	40	0.5– 0.7	66	11
8.0– 9.9	50	5.0– 5.9	66	0.8– 1.0	67	6
10.0–11.9	72	6.0– 6.9	74	1.1– 1.3	34	1
12.0–13.9	51	7.0– 7.9	61	1.4– 1.6	45	2
14.0–15.9	38	8.0– 8.9	55	1.7– 1.9	20	2
16.0–17.9	27	9.0– 9.9	41	2.0– 2.9	40	4
18.0–19.9	18	10.0–10.9	27	3.0– 3.9	13	2
20.0–21.9	12	11.0–11.9	11	4.0– 4.9	10	
22.0–25.9	12	12.0–12.9	9	5.0–10.1	14	
26.0–32.2	9	13.0–18.5	11			
					384	47
13.0†	340	7.4†	420	1.4†	431	
12.0‡	340	7.2‡	420	0.9‡	431	

* Average daily production.
† Mean.
‡ Median.

portance of residential sales increased sharply (from 52 per cent for the smallest companies to 68 for the largest), while both commercial and industrial sales declined, in several cases to negligible amounts. The qualification must be added that these statistical results depend entirely on how the utilities reporting chose to define the three service classes.

Information on what is generally classed as public or municipal use was meager, because it was not specifically requested. A careful review of those cities reporting indicated that municipal use varied most generally from 2 to 10 per cent of sales; 5 per cent would be representative. A slight majority of the publicly owned utilities reporting charged for all such use; the rest charged for roughly half and wrote off the remainder as free service. For privately owned utilities, the amount of free service was negligible.

The effect of rates on water use has long been of interest, and the breakdown provided valuable information on this point. Residential use was found (Fig. 5) to vary from 50,000 to 100,000 gal per year, correlating very generally with a trend in monthly water rates from \$5 to \$1 per 1,000 cu ft.

A similar study of the interrelationship of rates and total production yielded an almost identical pattern, with the water use values ranging from 100 gpcd (at the \$5 rate) to 180–200 gpcd at the \$1 rate.

There can be little argument about the basic influence of the cost of any product upon its use. Yet, after considerable statistical study, the authors remain skeptical that a rate adjustment has the prompt, proportionate effect on water use which the above relationships suggest. The authors feel that most rate adjustments are moderate enough and that habits of water use are sufficiently stable to consign the rate factor to a distinctly minor role as an influence on fluctuations in water use.

Distribution System

Distribution main mileage (4-in. mains and larger) was found (Table 8) to vary generally from almost 3 miles per 1,000 population for the smallest cities surveyed to about 2 miles for the largest cities. No significant change since 1945 was apparent.

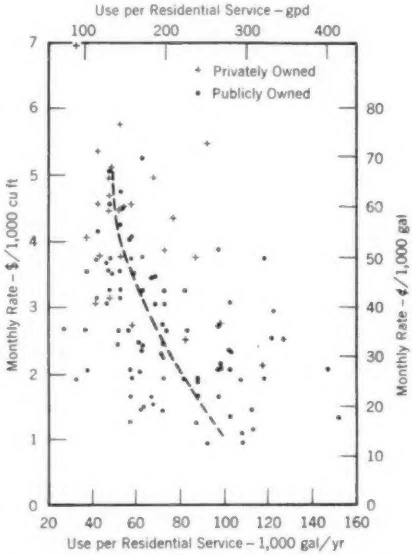

Fig. 5. Effect of Rates on Residential Use

Lower rates for first 1,000 cu ft appear to correlate with increased use.

The number of hydrants per mile of main was found (Table 9) to be most commonly 6 or 7,* while the number of

* This was 10 per cent above the 1945 figure, perhaps because the 1945 returns were less careful to distinguish between transmission and distribution mains in reporting mileage.

TABLE 10

Distribution System Water Temperatures

Region and Source	No. of Cities	Water Temperature—°F					
		Min.	Max.	Mean	1st Q.	Median	3rd Q.
New England							
Surface							
Jan.	28	33	52	39	35	39	40
Jul.	28	50	79	67	64	70	79
Ground							
Jan.	2	52	56	54			
Jul.	2	52	62	57			
Middle Atlantic							
Surface							
Jan.	37	33	57	38	35	38	40
Jul.	37	55	82	70	65	70	75
Ground							
Jan.	11	43	60	52	50	52	55
Jul.	13	50	75	60	55	60	65
South							
Surface							
Jan.	56	36	68	47	42	46	51
Jul.	57	45	87	79	76	80	84
Ground							
Jan.	30	50	80	68	62	70	75
Jul.	30	52	90	73	67	71	80
N. East Central							
Surface							
Jan.	41	32	45	37	34	36	40
Jul.	41	55	82	72	69	70	76
Ground							
Jan.	25	50	65	54	52	54	56
Jul.	25	52	68	58	55	56	60
N. West Central							
Surface							
Jan.	39	32	50	38	34	36	40
Jul.	39	48	90	73	63	75	80
Ground							
Jan.	44	34	65	53	50	54	56
Jul.	45	40	73	58	54	57	62
Mountain							
Surface							
Jan.	9	32	50	41	(35)	40	(48)
Jul.	9	54	67	59	(56)	58	(61)
Ground							
Jan.	2	65	71	68			
Jul.	2	71	84	78			
Pacific Coast							
Surface							
Jan.	19	35	61	46	39	46	52
Jul.	19	53	77	65	59	65	68
Ground							
Jan.	17	48	68	63	61	67	68
Jul.	18	51	75	66	64	68	69

TABLE 10—*Distribution System Water Temperatures (contd.)*

Region and Source	No. of Cities	Water Temperature—°F					
		Min.	Max.	Mean	1st Q.	Median	3rd Q.
US							
Surface							
Jan.	229	32	68	41.0	35	40	45
Jul.	230	45	90	71.8	65	72	78
Ground							
Jan.	131	34	80	58.1	52	56	65
Jul.	135	40	90	62.9	55	60	70
Surface & ground							
Jan.	360	32	80	47.2	38	45	55
Jul.	365	40	90	68.5	60	70	76
January & July							
Surface	459	32	90	56.5	40	55	71
Ground	266	34	90	60.5	54	58	68
US average	(725)	32	90	58.0	45	58	70

TABLE 11

Distribution System Pressures

Pressure *psi*	Business District Min.	Business District Max.	Residential District Min.	Residential District Max.
	No. of Cities			
3–9			5	
10–19			14	
20–29	11		63	
30–39	29	1	115	1
40–49	91	12	124	13
50–59	101	44	82	48
60–69	89	96	31	77
70–79	58	79	10	63
80–89	35	62	5	49
90–99	19	54	1	45
100–109	11	47		51
110–119	4	21		19
120–129	3	21	1	38
130–139	1	6		13
140–149		12		12
150–159		3		12
160–169		4		8
170–179		2		4
180–250		3		13
61*, 85†	452	467		
42*, 93†			451	466

* Mean minimum. † Mean maximum.

valves (Table 9) was most frequently in the range of 10–12 per mile of main. No significant trend by size of city was apparent for either.

Storage in terms of average daily production was also reviewed. The intention was to include all storage actually available on the distribution system, whether ground or elevated, gravity or pumped, but to discount impounding storage used primarily as a supply source. The result was a rather broad spread, but without important variation by size of city. The range of greatest frequency was 0.5–1.5 days' production volume (Table 9).

Water Temperature

Average January and July distribution system water temperature data are summarized in Table 10. For surface supplies a difference of 30°F between these months (most frequent values: 40° for January and 70° for July) was typical, with variations as high as 45° and 50° reported. For ground supplies, the difference was most generally on the order of 5°F; most frequent values were 58° for January and 63° for July. For all supplies, seasons, and

sections of the country, the mean (and median) water temperature was 58°F.

Pressure

The survey form requested maximum and minimum pressures for both the business and the residential districts of each distribution system. Frequency data (Table 11) indicate, in very general terms, that business district pressures ranged most typically from 60 to 85 psi, while those in residential districts were subject to greater variation, from roughly 40 to 90 psi.

TABLE 12

Employees, by Treatment Types

Ownership and Treatment Type	No. of Cities	No. of Employees per 1,000 Retail Pop.					
		Min.	Max.	Mean	1st Q.	Median	3rd Q.
Publicly owned							
Minor	71	0.29	2.93	0.84	0.57	0.69	1.10
Filtration	92	0.32	2.86	0.98	0.70	0.92	1.16
Softening	53	0.45	2.00	0.96	0.75	0.91	1.16
All	216	0.29	2.93	0.93	0.66	0.88	1.10
Privately owned	32	0.24	1.14	0.75	0.57	0.76	0.88
US	248	0.24	2.93	0.92	0.66	0.86	1.07
US (1950)	394	0.23	3.10	0.89	0.62	0.81	1.09

TABLE 13

Population per Residential Service

Pop. Group	No. of Cities	Retail Pop. per Residential Service					
		Min.	Max.	Mean	1st Q.	Median	3rd Q.
1	99	2.8	7.1	4.3	3.6	4.1	4.6
2	66	3.0	8.0	4.4	3.8	4.3	4.8
3	45	3.3	7.2	4.6	4.1	4.4	4.8
4	26	3.5	6.7	4.9	4.1	4.6	5.7
5	9	3.9	6.4	4.8	(4.1)	4.5	(5.3)
6	22	3.7	8.6	5.5	4.4	5.4	6.3
1–6	267	2.8	8.6	4.5	3.9	4.3	5.0

TABLE 14

Services per 1,000 Population, by Service Class

Service Class	No. of Cities	No. of Services per 1,000 Retail Pop.					
		Min.	Max.	Mean	1st Q.	Median	3rd Q.
Residential	267	115	360	230	200	230	255
Commercial	196	0	55	19	10	18	24
Industrial	196	0.0	9.3	1.9	0.6	1.4	2.6
Public	254	0.0	5.0	1.2	0.5	1.0	1.7

Employees

Analysis indicated that mean and median values for the number of full-time water department employees (Table 12) were very close to 0.9 per 1,000 population—an increase of 5 per cent in the 1950–55 period. The range of most common occurrence was 0.6–1.0 per 1,000 population.

Both treatment type and ownership were found to affect the number of employees reported; utilities providing filtration or softening required approximately 20 per cent more employees than those classified in the minor-treatment group. Privately owned utilities as a group reported only 5 employees for every 6 in publicly owned utilities.

Service Accounts

Dividing the retail population by the number of residential customers yielded data on the number of persons per residential service. In these terms, the most frequent range was 4–4.5 persons; and it was also found (Table 13) that the number of persons trended from just over 4 in the lowest population group to roughly 5.5 in the largest. Undoubtedly, the number and size of multiple dwellings in the larger cities constitute a major factor in this trend.

For the other service classes, the calculation was reversed, to find the number of customer accounts per 1,000 population. Analysis indicated close to 20 commercial and approximately 2 industrial and 1 municipal service per 1,000 population. Together with the 230 (mean and median) residential services per 1,000, this gives a total of approximately 250 accounts of all types per 1,000 population for the "average" water utility (Table 14)—however, this figure ranged from less than 200 to almost 400.

Metering

Commercial and industrial services were very nearly completely metered; this was not the case for residential or municipal accounts. The data available for these two service classes are summarized in Table 15. In regard to metering, as in the number of customer services, the difference between privately and publicly owned utilities was not significant.

Billing Periods

Meter reading and billing periods ranged from monthly to annual intervals and often varied for different service classes within a utility. By far the majority of commercial and industrial services were read and billed monthly, while almost half the cities reported billing residential customers quarterly, and some even less frequently. Residential billing periods also varied with size of city (Table 16); in the smallest cities, 50 per cent were on a monthly basis, while in the largest population groups only 10–15 per cent were billed monthly and 50–60 per cent quarterly. Bimonthly residential billing also was more common in larger cities.

TABLE 15

Frequency Data on Residential and Public Services Metered

Per Cent Metered	No. of Cities	
	Residential Services	Public Services
0	13	38
1–10	13	2
11–89	14	36
90–99	25	5
100	376	186
Total	441	267

Penalties and Discounts

A total of 466 cities answered the questions on penalty or discount provisions. Only 45 of these cities indicated discounts to be in effect, ranging from 3 to 20 per cent of the bill, with 10 per cent the most common discount (30 cities). Of the 217 cities with penalty provisions for late payment—ranging from 1 to 20 per cent of the bill, or fixed amounts up to $2.50—104 charged 10 per cent. Billing was reported as net by 204 cities.

Minimum Charge and Allowance

The minimum monthly charge for residential service (Table 17) ranged most commonly from $1.00 to $1.50. The amount allowed on the minimum charge (Table 17) ranged most often between 300 and 500 cu ft. Only 32

TABLE 16

Residential Billing Periods

Pop. Group	No. of Cities	Percentage of Cities Billing:			
		Monthly	Bimonthly	Quarterly	Semiannually or Annually
1	170	50	4	39	7
2	114	39	14	42	5
3	68	31	13	51	5
4	57	38	9	48	5
5	20	15	15	60	10
6	30	11	25	52	12
1–6	459	39	10	44	7

TABLE 17

Monthly Minimum Charge and Allowance

Group	No. of Cities	Min.	Max.	Mean	1st Q.	Median	3rd Q.
Minimum Charge per Month—$							
Public	421	0.00	3.50	1.20	0.80	1.15	1.50
Private	58	0.00	3.15	1.52	1.25	1.50	1.85
US	479	0.00	3.50	1.25	0.90	1.20	1.50
US (1950)	339	0.15	4.25	1.00	0.67	1.00	1.25
Allowance on Minimum Charge—*cu ft*							
Public	370*	35	3,333	430	275	400	525
Private	51†	100	890	360	267	400	400
US	421	35	3,333	420	267	400	500
US (1950)	316	33	2,500	480	300	400	600

* Exclusive of 29 cities with service charge (no allowance).
† Exclusive of 3 cities with service charge (no allowance).

TABLE 18

Frequency Data on Annual Hydrant Charges

Annual Charge per Hydrant $	No. of Cities	
	Publicly Owned	Privately Owned
none	128	1
less than 10	9	1
10–29	46	15
30–49	40	10
50 or more	20	15
Total	243	42

of 453 cities reported a service charge, under which no allowance was granted but which was in addition to actual use charges.

The difference between publicly and privately owned utilities was quite pronounced. The latter allowed about 10 per cent less water on the minimum bill while maintaining minimum charges at a level 33 per cent above that of publicly owned utilities.

Public Fire Service Charge

With respect to charges for public fire service, privately owned utilities were roughly one-third higher than publicly owned. The schedule of charges ranged most commonly from $10 to $50 a year per hydrant (Table 18).

Billing Written off

Of the 372 cities reporting on billing written off as uncollectible, the majority gave a figure of less than 0.1 per cent. The data are summarized in Table 19. No significant difference was found between publicly and privately owned utilities in this regard.

Rate Schedules

In considering rates and finances, the differences between publicly and privately owned utilities were so substantial that it was believed more practical to evaluate them separately from this point on. Further references to privately owned utilities will be reserved for a later section (p. 1561). Similarly, further comparisons with previous surveys will be withheld for the concluding section of the analysis (p. 1564).

In the data survey, rates were tabulated for 1,000, 10,000, 100,000, and 1,000,000 cu ft per month. Analysis by population groups indicated a decrease in rates with increasing size, from mean and median values of about $2.90 per 1,000 cu ft for Group 1 to $2.00 for Group 6. By volume groups (Table 20), a similar but stronger trend was apparent, the rate decreasing from about $3.20 per 1,000 cu ft for Group 1 to about $2.00 for Group 7.

For 10,000 cu ft per month, rates varied typically from $21.50 for Volume Group 1 to $16.50 for Volume Group 7. For 100,000 and 1,000,000 cu ft, typical charges were $130 and $1,030, respectively, with little variation by size or volume group.

Analysis by treatment types (Fig. 6) indicated that rates were lowest for those in the minor-treatment classification, as could be expected in view of their lower operating costs. Rates for

TABLE 19

Frequency Data on Billing Written off

Per Cent of Total Billing Written off	No. of Cities
none	126
less than 0.01	44
0.01–0.09	61
0.10–0.24	50
0.25–0.59	45
0.60–1.00	27
over 1.00	19
Total	372

TABLE 20

Rate Schedules of Publicly Owned Utilities, by Volume Groups*

Volume Group	No. of Cities	Monthly Rate—*$/1,000 cu ft* Min.	Max.	Mean	1st Q.	Median	3rd Q.
1	82	1.50	5.75	3.21	2.50	3.18	3.64
2	117	0.98	7.50	2.75	2.03	2.69	3.29
3	58	1.30	6.00	2.74	2.08	2.69	3.33
4	56	0.68	4.85	2.41	1.75	2.20	2.98
5	41	1.00	5.20	2.35	1.78	2.15	2.80
6	43	0.80	4.18	2.10	1.69	2.08	2.37
7	35	0.90	3.29	2.02	1.43	2.04	2.56
1–7	432	0.68	7.50	2.62	1.93	2.50	3.19
1–7 (1950)	334	0.60	5.41	2.23	1.50	2.15	2.75
1–7 (1945)	334	0.50	4.25	1.89	1.35	1.70	2.30
		Monthly Rate—*$/10,000 cu ft*					
1	82	8.00	42.50	22.40	17.40	20.80	27.35
2	116	4.33	40.15	19.15	13.90	19.60	22.70
3	58	8.75	43.60	19.70	15.20	18.90	22.80
4	56	6.13	44.50	17.70	12.20	15.80	21.65
5	41	6.85	34.00	17.30	13.20	16.25	20.00
6	43	7.80	29.60	16.85	13.35	17.00	20.25
7	35	6.60	30.25	16.80	10.90	16.35	21.25
1–7	431	4.33	44.50	19.00	13.50	18.45	22.75
1–7 (1950)	334	3.75	44.66	16.80	12.00	16.00	20.50
1–7 (1945)	335	3.00	32.81	14.10	10.00	13.50	17.50
		Monthly Rate—*$/100,000 cu ft*					
1	79	57.91	327.40	151	109	143	185
2	114	35.55	296.95	134	96	136	165
3	58	50.00	234.18	134	95	127	177
4	56	36.30	244.00	126	88	113	158
5	41	61.83	227.96	120	93	112	145
6	42	54.60	299.60	126	93	123	145
7	35	62.26	270.00	133	100	127	170
1–7	425	35.55	327.40	134	93	126	162
1–7 (1950)	334	26.75	375.00	117	82	106	139
1–7 (1945)	334	15.00	250.17	93	67	87	120
		Monthly Rate—*$/1,000,000 cu ft*					
1	66	363	3,207	1,180	760	970	1,530
2	98	161	2,382	1,110	680	1,060	1,490
3	52	245	2,253	1,080	750	970	1,210
4	52	258	2,221	1,020	650	990	1,210
5	40	321	1,637	960	700	930	1,150
6	41	409	1,800	960	750	940	1,090
7	34	517	2,700	1,090	730	1,000	1,250
1–7	383	161	3,207	1,060	720	1,010	1,270
1–7 (1950)	331	146	3,750	936	640	805	1,110
1–7 (1945)	329	93	2,500	786	520	700	1,000

* For privately owned utilities, see Table 33.

cities in the filtration class were generally 20 per cent higher throughout the rate steps; for softening, rates for the smaller quantities were essentially the same as for filtration, but as much as 20 per cent above filtration at the 1,000,000-cu ft step.

Total Revenue

The data survey requested information on revenue from each customer category, from public or municipal service, from public and private fire service, and from miscellaneous sources. This revenue total was then divided by retail population served to give a per capita revenue figure.

In these terms, mean and median values for annual per capita revenue for 376 cities were $10.65 and $10.05, respectively, although the returns ranged from less than $4 to more than $30. The range of greatest frequency (Fig. 7) was $8–$10 per capita. Trends by either population or volume (Table 21) were lacking. (It should be noted again that this and succeeding sections are concerned only with publicly owned utilities.)

As derived, this per capita figure is open to serious criticism because many utilities, particularly the larger ones, serve substantial wholesale demands not reflected in the population total. Also, the miscellaneous income reported, much of which is nonoperating, varies greatly and serves to distort further an analysis of water utility operations as such.

Calculation of total revenue per million gallons produced (Table 21) is somewhat more realistic. This figure

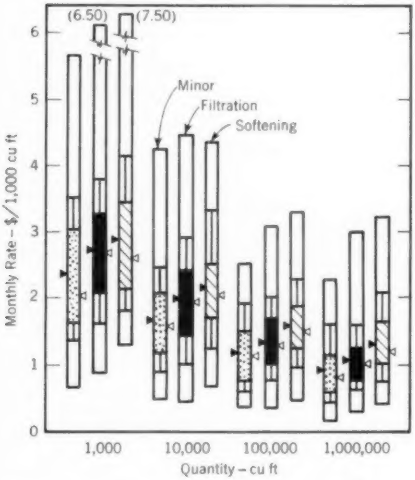

Fig. 6. Monthly Rates, by Treatment Types

Rates charged by publicly owned utilities with minor treatment, filtration, or softening are compared.

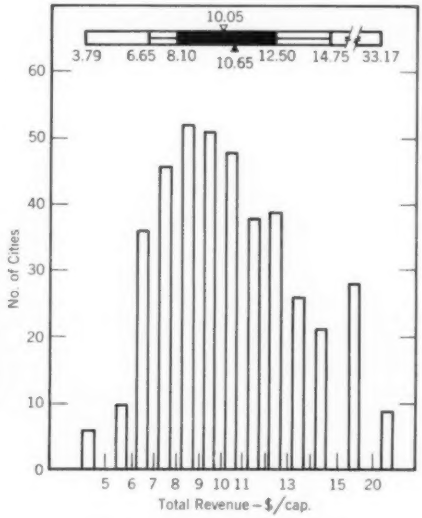

Fig. 7. Per Capita Revenue

These data, based on retail population served, are for 376 cities.

was found to vary from roughly $290 for Volume Group 1 to about $160 for Volume Group 7.

Water Sales Revenue

Analysis of revenue was carried one step further, to determine water sales revenue per million gallons. For this purpose, only income from residential, commercial, industrial, and municipal customers was totaled and then divided by production volume. Water sales revenue, amounting to approximately 92 per cent of total revenue, was found to vary appreciably with population but was still more affected by volume (Table 21) ranging from about $265 per million gallons for Volume Group 1 to $145 for Volume Group 7.

Analysis by treatment types indicated that water sales revenue per million gallons for cities providing

TABLE 21

Revenue of Publicly Owned Utilities, by Volume Groups

Volume Group	No. of Cities	Total Revenue $/cap.*		Total Revenue $/mil gal†		Water Revenue $/mil gal†	
		Mean	Median	Mean	Median	Mean	Median
1	67	9.98	9.70	300	278	279	255
2	98	10.64	10.25	235	230	220	210
3	53	11.54	10.75	222	212	201	195
4	48	10.92	10.80	207	185	189	172
5	36	10.92	9.85	212	200	195	183
6	40	10.66	10.10	189	187	176	176
7	34	9.48	8.80	160	152	148	146
1–7	376	10.65	10.05	228	214	210	196
1–7 (1950)	312	7.94	7.71	182	172		
1–7 (1945)	355	5.98	5.64	151	143		

* Per capita figures based on retail population served.
† Per million gallons produced.

TABLE 22

Major Sources of Revenue of Publicly Owned Utilities, by Population Groups*

Pop. Group	No. of Cities	Per Cent of Total Revenue					
		Resid. Svces.		Coml. Svces.		Ind. Svces.	
		Mean	Median	Mean	Median	Mean	Median
1	24	63	63	16	14	16	12
2	17	55	54	18	13	20	21
3	15	59	58	17	16	14	14
4	11	54	56	20	21	17	17
5	3	47	47	20	12	24	27
6	8	52	51	25	24	18	21
1–6	78	57	56	18	17	17	16

* Excluding Wisconsin.

softening was approximately $20 higher than for those in the filtration class, while the filtration group, in turn, was collecting $30 more than the revenue received by utilities in the minor-treatment class. The mean and median figures, respectively, were: for 130 utilities with minor treatment—$178, $170 per million gallons; for 158 with filtration—$218, $205; for 88 with softening—$242, $220.

Revenue per Service

From data on the number of services and on revenue from each service class, the mean annual revenue per service in each class was calculated for more than 100 utilities (Fig. 8). The results for residential services were particularly interesting. Mean annual revenue per service was $25; the median value was $23; the range of most common occurrence was $18–$24, with peak frequency at $21. There was, however, no variation with population or volume, the broad implication being that such factors as the charge for water and per capita use balance each other.

It is also worth noting that, at 4 or more persons per service, the per capita annual revenue for residential service is slightly short of $5, a far cry from the $10+ per capita total revenue previously mentioned.

For commercial services, annual revenue ranged most commonly from $60 to $80 per account. The variation in annual revenue from industrial services was, of course, greater; the most common range was about $300–$800 per service, but for many cities, this figure was in thousands of dollars.

From these values and from data in the section on water use per service, it can be stated in highly generalized terms that residential customers were paying for their water at the rate of approximately $2.25 per 1,000 cu ft; commercial customers were paying about $1.50 per 1,000 cu ft for the water used, and industrial customers about $0.75. These values apply to publicly owned utilities only.

Sources of Revenue

A further detailed study (Fig. 9, Table 22) was made of 78 publicly owned utilities providing a complete breakdown of revenue from each service class, and from fire service charges and miscellaneous sources as well. These cities were fairly representative in size and location (except that cities in Wisconsin were excluded; because of unique revenue and tax procedures,

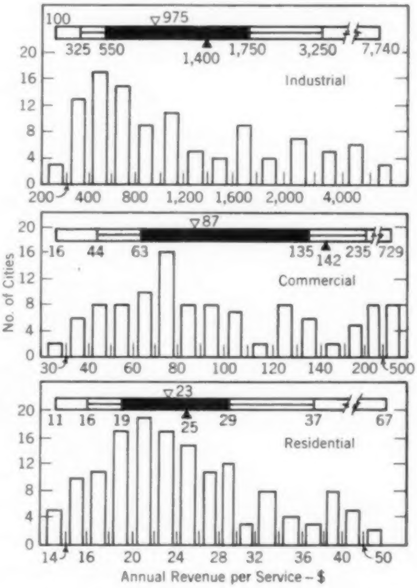

Fig. 8. Annual Revenue per Service

All data are for publicly owned utilities only; residential, 150 cities; commercial, 112 cities; industrial, 111 cities.

the 20 cities reporting from that state are dealt with separately—see p. 1560).

The largest single source of revenue was from residential sales, ranging from over 60 per cent of total revenue for Population Group 1 to 50 per cent for Population Groups 5 and 6 (Table 22). Commercial sales increased in importance from 15 to about 25 per cent of total revenue with increasing size; industrial revenue varied erratically with size of city between limits of 15–25 per cent of total revenue.

For the 78 cities as a group (Fig. 9), residential customers provided 56 per cent of the total revenue, commercial customers 18 per cent, and industrial 17 per cent. (It may be pertinent to point out that industrial customers as a group were paying only one-sixth of the bill while consuming one-third of the water sold.) These three classes together furnished 91 per cent of the revenue.

Adding the approximately 1 per cent reported as income from municipal sales brings the sum of water sales revenue to 92 per cent of total revenue.

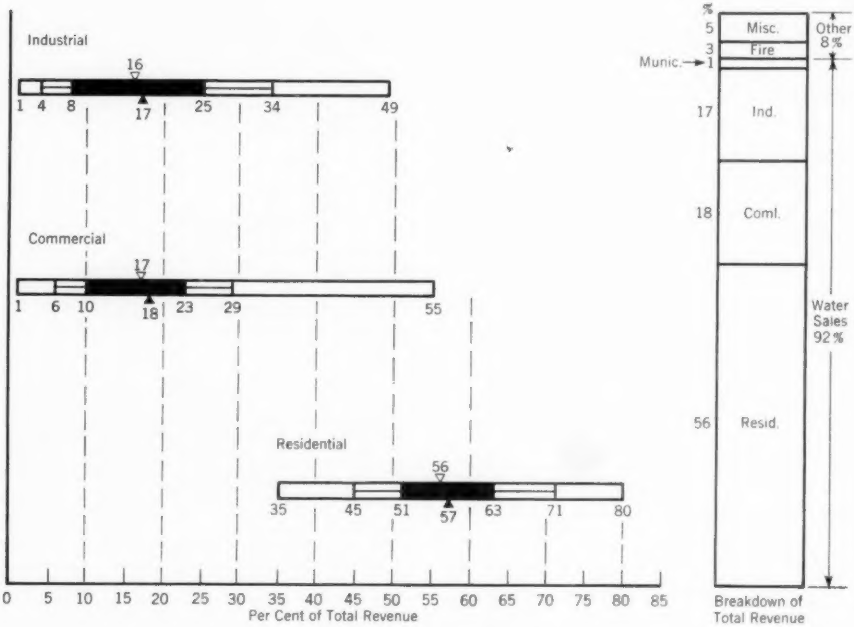

Fig. 9. Sources of Revenue

The three bar graphs at left show the percentage of total revenue obtained from the three main service classes by 78 publicly owned utilities throughout the United States (excluding Wisconsin). The chart at right shows the breakdown of total revenue for these cities.

The sum of public and private fire service charges (still excluding Wisconsin) was found to account for an additional 3 per cent, and miscellaneous income provided the remaining 5 per cent of total revenue. Although the sum of these minor sources of income averaged only 9 per cent for the 78 cities under discussion, some utilities reported income from one or another of these sources in amounts constituting as much as 15–20 per cent of total revenue.

TABLE 23

Operation and Maintenance Costs of Publicly Owned Utilities, by Volume Groups

Volume Group	No. of Cities	Costs—$/cap.*		No. of Cities	Costs—$/mil gal†	
		Mean	Median		Mean	Median
1	65	5.55	5.28	67	163	155
2	104	5.63	5.36	98	122	121
3	55	5.77	5.34	53	114	112
4	49	5.82	5.22	48	109	96
5	37	4.90	4.79	36	98	90
6	43	5.35	5.04	40	92	88
7	35	4.93	4.72	34	83	81
1–7	388	5.50	5.18	376	118	110
1–7 (1950)	314	4.33	3.97	311	98	88
1–7 (1945)	352	3.01	2.75	355	76	68

* Per capita figures based on retail population served.
† Per million gallons produced.

Free Service Value

Free service value may be considered potential revenue which is written off as a concession or courtesy to municipal or other governmental customers, schools, hospitals, and the like. In many cases it includes an estimate, often nominal, of fire service value. Of the 234 cities answering the question on this subject, 98 reported no free service; 48 reported an amount equivalent to 4 per cent or less of their total annual revenue; 40, from 4 to 8 per cent; 29, from 8 to 16 per cent; and 19, over 16 per cent.

Operation and Maintenance Costs

The sum of operation and maintenance costs of publicly owned utilities divided by the retail population served gave per capita figures varying from $2 to over $12, with mean and median values being $5.50 and $5.18, respectively (Table 23); the range of most common occurrence was $4–$6 per capita. This cost figure, based on retail population only, is again open to criticism because a number of cities serve large areas on a wholesale basis. As was true for per capita revenue, variation by size or volume was lacking.

When calculated in terms of dollars per million gallons produced, operation and maintenance costs were found to vary somewhat by population group but a good deal more by volume group—from about $160 for Volume Group 1 to just over $80 for Volume Group 7.

TABLE 24

Total Expense of Publicly Owned Utilities

Pop. Group	No. of Cities	Total Expense—$/cap.*		Volume Group	No. of Cities	Total Expense—$/mil gal†	
		Mean	Median			Mean	Median
1	146	6.00	5.88	1	67	172	160
2	91	5.87	5.36	2	98	126	124
3	54	5.41	5.21	3	53	118	112
4	54	5.21	5.19	4	48	114	102
5	17	5.16	4.92	5	36	108	94
6	26	5.03	4.87	6	40	96	95
				7	34	85	83
1–6	388	5.68	5.36				
				1–7	376	123	113

* Per capita figures based on retail population served.
† Per million gallons produced.

These values are slightly more than half of total revenue.

Analysis by treatment types indicated that cities in the filtration class reported operation and maintenance costs about $20 per million gallons above those in the minor-treatment group, with softening costs being $30 per million gallons above filtration. These cost differentials were in reverse order from those noted for revenue (filtration $30 over minor, softening $20 over filtration), but the overall difference between the minor and softening groups was roughly $50 per million gallons for both expense and revenue. The mean and median cost figures, respectively, were: for 130 utilities with minor treatment—$97, $92 per million gallons; for 158 with filtration—$118, $112; for 88 with softening—$148, $141.

Taxes and Miscellaneous Expense

Taxes and miscellaneous expense were each reported by not more than one-fourth of the publicly owned utili-

TABLE 25

Earnings of Publicly Owned Utilities

Pop. Group	No. of Cities	Earnings—$/cap.*		Volume Group	No. of Cities	Earnings—$/mil gal†	
		Mean	Median			Mean	Median
1	146	4.75	4.30	1	67	128	112
2	91	5.10	4.75	2	98	108	93
3	54	4.62	4.45	3	53	104	97
4	54	5.09	5.18	4	48	93	82
5	17	4.71	4.58	5	36	104	98
6	26	4.19	3.75	6	40	92	85
				7	34	75	66
1–6	388	4.80	4.55				
				1–7	376	104	92

* Per capita figures based on retail population served.
† Per million gallons produced.

ties surveyed, and were quite small, with few exceptions. Together they constituted approximately $0.20 per capita as an annual expense item, or about $4 per million gallons, with taxes the smaller item.

In tabulating the survey data, an effort was made to include as an expense item only taxes actually levied by a branch of government, and to show all contributions or assessments in lieu of taxes as transfers to general funds (Survey Table 4, Col. 37). There remained 81 publicly owned utilities which paid taxes. Of these, 42 reported taxes amounting to 1 per cent or less of total revenue; 21, from 1 to 3 per cent; and 18, over 3 per cent.

Out of 90 cities reporting miscellaneous expenses, the amount was 1 per cent or less of total revenue in 26 cases; 1–3 per cent in 25 cases; and over 3 per cent in 39 cases.

Total Expense

As defined for purposes of this data survey and analysis, total expense (Table 24) is the sum of operation and maintenance costs, taxes, and miscellaneous expense. In these terms, total expense for publicly owned utilities was generally about $5.50 per capita or $118 per million gallons. Total expense amounted to roughly 53 per cent of total revenue.

TABLE 26

Disposition of Total Revenue of Publicly Owned Utilities *

1	2	3	4	5	6	7	8	9	10
Volume Group	No. of Cities	Total Revenue	Operation and Maintenance	Taxes and Miscellaneous	Debt Service†	Capital Expense	Paid to General Funds	Depreciation‡ and Reserves	Total Col. 6–9
		Amount—*$/mil gal*§							
1	47	289	159	7	59	29	10	25	123
2	79	232	122	3	45	29	11	22	107
3	45	217	113	2	40	24	10	28	102
4	38	196	103	5	36	27	10	15	88
5	30	206	94	7	45	27	16	17	105
6	33	188	90	5	40	20	18	15	93
7	31	156	82	2	33	14	11	14	72
1–7	303	221	114	4	44	26	12	21	103
1–7 (1950)	181	177	93	3	(24)	(6)‖	(15)	(36)‖	81

* Data rounded off, using mean and median values. Total of Col. 4–9 equals Col. 3; difference between Col. 3 and sum of Col. 4 and 5 is defined as "earnings" and equals Col. 10. Wisconsin cities excluded.
† Interest, debt retirement reserve, and bonds retired.
‡ Cash only.
§ Per million gallons produced.
‖ As reported; however, wording of 1950 questionnaire permitted understatement of capital expense and overstatement of reserves.

Earnings

For want of a better term, the word "earnings" was used in the survey to mean the difference between total revenue and total expense as previously defined. Earnings (Table 25) ranged

from more than \$16 per capita down to a negative value or "loss" of \$1, with the most common range being \$4.50–\$5 per capita annually. In terms of production, this difference ranged from \$380 per million gallons down to a value of minus \$33, with \$90–\$105 per million gallons being most common.

TABLE 27

Frequency Data on Disposition of Earnings by Publicly Owned Utilities *

Amount \$/mil gal†	Debt Service‡	Capital Expense	Paid to General Funds	Depreciation§ and Reserves
	No. of Cities			
withdrawal				17
none	40	77	135	57
under 10	24	12	27	30
10–19	19	31	19	33
20–29	26	24	11	24
30–39	20	20	7	26
40–49	16	17	7	10
50–59	11	9	5	7
60–69	20	13	3	3
70–79	11	7	3	3
80–89	6	6	2	3
90–99	8	2	2	2
100–149	20	4	2	8
150 or more	4	3	2	2

* Analysis for 225 cities (in Volume Groups 2–6) reporting complete disposition. Wisconsin cities excluded.
† Per million gallons produced.
‡ Interest, debt retirement reserve, and bonds retired.
§ Cash only.

No trend on a per capita basis was observed in the difference between revenue and expense. On a volume basis, however, this difference was found to vary from about \$120 per million gallons for Volume Group 1 to \$70 for Volume Group 7, with the important qualification that the average values for Groups 2 through 6 did not vary a great deal from \$100. For 225 publicly owned utilities in these five volume groups (again excluding Wisconsin cities because of their distinctive accounting procedures), a detailed analysis was made of the disposition of earnings (Table 26 and 27, Fig. 10)—

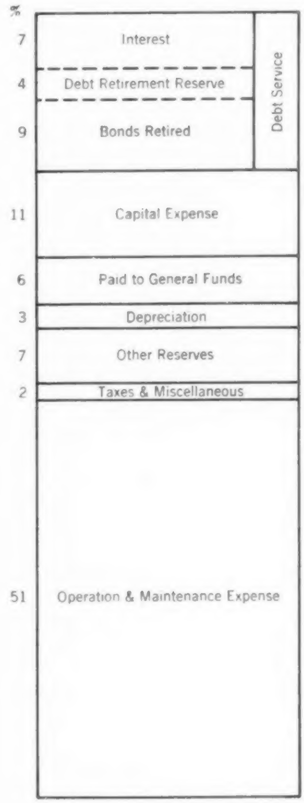

Fig. 10. Disposition of Revenue

The 225 publicly owned utilities on which this chart is based had a total revenue of about \$213 per million gallons produced (average of mean and median). "Depreciation" refers only to cash actually set aside. "Other reserves" includes all surplus funds after other disposition as shown.

that is, of the 47 per cent of total revenue remaining after total expenses were subtracted.

Disposition of Earnings

The data survey requested publicly owned utilities to provide a breakdown of earnings disposition into: debt service (interest, debt retirement, and reserve for debt retirement); capital expense; payments to general funds or regional authorities; and reserves (cash depreciation reserve and general utility reserve or surplus).

Debt service proved to be the largest element, accounting for 20 per cent of total revenue; only 40 of the 225 cities in this analysis reported nothing in this category. Next was capital expenses (11 per cent), reported by two-thirds of the cities; then reserves (10 per cent), reported by three-fourths; finally, payments to general funds, reported by only 90 cities, accounted for the remaining 6 per cent. This disposition appeared to be essentially unaffected by size of city.

Only 50 of the 225 cities set aside funds for actual cash depreciation reserves; 82 cities allocated an amount for depreciation as an accounting record only, without actually setting funds aside; 133 reported funds allocated to other reserves or to surplus; and 74 reported either no disposition to reserves of any kind or an actual withdrawal from reserves.

Operating Ratio

As defined in the survey tabulation, operating ratio is the proportion of total expense to total revenue. For 388 publicly owned utilities the mean value was 1:2.0 and the median 1:1.8; the greatest frequency was in the range of 1:1.4 to 1:2.1. Cities of medium size appeared to be achieving mildly better coverage of expense than either the smaller or larger cities.

Capital Additions

The survey form requested data on funds raised for capital additions from prior earnings, from general-obligation or revenue bonds, and from other sources. This information did not lend itself easily to analysis, but some general comments are possible.

TABLE 28

Sources of Funds for Capital Additions, Publicly Owned Utilities

Pop. Group	No. of Cities	Prior Earnings	G.O. Bonds	Revenue Bonds	Bank Loans and Other
		No. of Cities*			
1	95	78	12	16	5
2	76	58	17	15	2
3	42	28	8	13	2
4	39	32	10	18	—
5	13	9	1	9	1
6	20	17	5	7	3
1–6	285	222	53	78	13
	Total Raised	Percentage of Funds Raised			
1	100	29	39	29	3
2	100	26	49	24	1
3	100	20	14	64	2
4	100	20	24	56	—
5	100	36	5	54	5
6	100	44	24	25	7
1–6†	100	27	33	38	2

* As some cities reported more than one source, total cities in last four columns exceed figures in second column.

† Percentages weighted by number of cities.

Total funds raised by publicly owned utilities were most commonly in the range of \$3–\$5 per capita. Over three-fourths of the 285 cities reporting raised at least a portion of needed

funds from prior or current earnings; 53 cities reported new financing through general-obligation bonds and 78 through revenue bonds (Table 28).

In terms of dollar volume, revenue bond financing raised more than 50 per cent of the money for Population Groups 3, 4, and 5, and 38 per cent for all cities reporting. General-obligation bonds were next with 33 per cent; prior earnings furnished 27 per cent; and all other sources, the remaining 2 per cent.

TABLE 29

Frequency Data on Reserves, Debt, and Book Value, for Publicly Owned Utilities

Amount $/cap.	Depreciation Reserve	Surplus in Reserve	Funded Debt	Book Value	
				Total Plant	Distr. System
	No. of Cities				
none	68	51	35		
under 10	45	107	56		
10–19	37	27	32	3	12
20–29	40	9	31	6	14
30–39	6	12	29	25	33
40–49	4	8	25	18	42
50–59	3	4	23	43	21
60–79	2	6	16	76	25
80–99		3	10	67	9
100 or more			11	73	4
17,* 16†	205				
12,* 5†		227			
33,* 29†			268		
82,* 76†				311	
48,* 45†					160

* Mean.
† Median.

TABLE 30

Book Value of Publicly Owned Utilities

Volume Group	No. of Cities	Book Value—*$1,000,000/mgd**					
		Min.	Max.	Mean	1st Q.	Median	3rd Q.
1	50	0.16	1.67	0.81	0.52	0.78	1.06
2	76	0.12	1.99	0.77	0.47	0.65	0.95
3	42	0.18	1.87	0.62	0.40	0.56	0.78
4	35	0.12	1.38	0.62	0.45	0.55	0.71
5	28	0.12	1.04	0.60	0.37	0.53	0.76
6	38	0.13	1.38	0.56	0.38	0.51	0.72
7	24	0.25	0.75	0.46	0.34	0.42	0.61
1–7	293	0.12	1.99	0.67	0.41	0.59	0.81

* Per million gallons produced daily.

For Population Groups 1 through 4, the amounts drawn from prior earnings were generally in the range of \$50,000–\$100,000, while the amounts raised by bonding were typically \$250,000–\$500,000 for a single bond issue.

Reserves and Debt

Information was also requested on depreciation reserve funds, surplus income held in reserve, and funded debt. After calculation on a per capita basis, these data were analyzed for typical values (Table 29).

Depreciation reserve funds of publicly owned utilities ranged generally from none to \$30 per capita, with mean and median values of \$17 and \$16 per capita, respectively. Surplus in reserve had an even broader spread, but was most common from none to \$10; mean and median values were \$12 and \$5 per capita. Funded debt exhibited the greatest variation, with mean and median values near \$30 per capita; many cities, however, reported over \$50 and some more than \$100 per capita of funded debt.

A further analysis was made for 194 cities reporting each of the above three items, after summing the values algebraically (considering debt a minus value and reserve funds as plus items). The result was a healthy picture (Fig. 11), with 110 cities on the minus side, 9 at zero, and 75 on the plus side, showing cash reserves exceeding debt. For the 194 cities, the overall mean value was a net debt of \$12, with a median value of only \$7 net debt per capita—certainly a nominal amount in view of the \$2 per capita allocated annually to debt service by public utilities.

Book Value

Book value of total plant was found to vary most commonly from \$50 to \$90 per capita for publicly owned utilities, with mean and median values near \$80 (Table 29). No trends by population or volume were apparent. The survey returns provided a breakdown of book value into four elements—supply and transmission, treatment and pumping, distribution system, and general property and equipment. A further study was made for the 160 cities providing this information in sufficient detail.

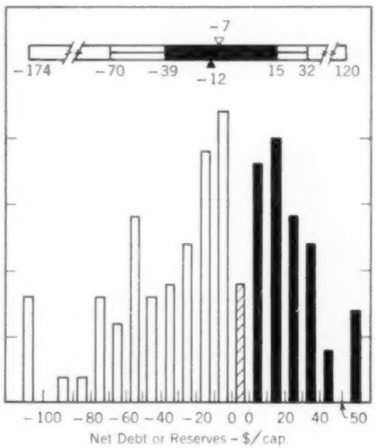

Fig. 11. Net Debt or Reserves

These data are for 194 publicly owned utilities providing sufficient data. (Black bars indicate excess reserves over debt; white bars, excess debt over reserves).

It was found that the distribution system alone was the largest single element in terms of book value; most typically, this item accounted for \$30–\$50 per capita (regardless of size of city), with mean and median values of \$48 and \$45, respectively (Table 29). General property and equipment was a minor item, accounting for only about \$2 per capita.

Supply and transmission, lumped with treatment and pumping, proved to be the variable factor, as could be anticipated. Book values for these elements totaled about $11 per capita for ground supplies with minor treatment, $37 for surface supplies with minor treatment, $30 for surface supplies with filtration, $20 for ground supplies with softening, and $35 for surface supplies with softening. Where the treatment works were not extensive, the supply and transmission facilities often more than made up the difference, as in the case of impounding reservoirs or major transmission projects.

Book value was also calculated in terms of total dollar value per million gallons per day production. In these terms, there was a definite variation from roughly $750,000 per million gallons per day for Volume Group 1 to somewhat under $500,000 for Volume Group 7 (Table 30). Variations were rather broad, as might be expected in view of the varied supply and treatment combinations included.

TABLE 31

Revenue Sources and Disposition—Wisconsin and Other Utilities *

Item	Wisconsin (Publicly Owned)		Publicly Owned (Except Wisconsin)		Privately Owned	
	$/mil gal†	*per cent*	*$/mil gal*†	*per cent*	*$/mil gal*†	*per cent*
Revenue sources						
Residential	67	40	123	56	203	62
Commercial	22	13	40	18	56	17
Industrial	38	23	38	17	36	11
Municipal	3	2	2	1	3	1
Fire	34	20	7	3	23	7
Miscellaneous	3	2	11	5	7	2
Total	167	100	221	100	328	100
Revenue disposition						
Op. and maint. costs	92	55	114	51	136	42
Taxes	1	1	2	1	81	25
Miscellaneous	2	1	2	1	3	1
To reserves	27	16	21	10	34	10
To general funds or dividends	25	15	12	6	35	11
Capital expense	8	5	26	11	8	2
Debt service‡	12	7	44	20	31	9
Total	167	100	221	100	328	100

* Figures are generalized from mean and median values.
† Per million gallons produced.
‡ Interest, debt retirement reserve, and bonds retired.

Comparison of Wisconsin and Other Publicly Owned Utilities

The returns from 20 publicly owned Wisconsin utilities as a group were sufficiently different in revenue pattern and disposition of available funds to merit separate analysis (Table 31).

These differences, in part at least, were very likely due to the control exercised by Wisconsin's Public Service Commission.

Although the sum of public and private fire service charges was only 3 per cent of total revenue for other publicly owned utilities, it amounted to 20 per cent for the Wisconsin cities reporting—certainly a much more realistic concept of fire protection value. (Consequently, the percentages represented by other sources of revenue were proportionately less.) Payments to general funds in lieu of taxes, however, represented 15 per cent of the revenue dollar in Wisconsin, compared to 6 per cent for other publicly owned utilities.

Wisconsin water rates were roughly 30 per cent less than elsewhere ($1.85 per 1,000 cu ft, as against $2.60), while per capita water use (160 gpcd) was about 20 per cent higher. Revenue per million gallons was $167, approximately 25 per cent less than elsewhere.

TABLE 32

Comparison of Publicly and Privately Owned Utilities *

Item	Public		Private		Per Cent Above or Below Public†
	Mean	Median	Mean	Median	
Production and sales					
Production—*gpcd*	139	126	120	102	−14
Distribution—*gpcd*	121	108	103	81	−16
Per cent sold	84	85	86	85	+ 1
Physical system					
Distribution mains—*miles/1,000 pop.*	2.6	2.5	2.3	2.3	−10
Valves per main-mile	13.0	12.0	12.6	12.4	0
Hydrants per main-mile	7.4	7.2	6.6	6.4	−11
Distribution storage—*days*	1.5	0.9	0.9	0.7	−33
Employees per 1,000 pop.	0.93	0.88	0.75	0.76	−17
*Financial**					
Annual revenue per service—$					
Residential	25	23	33	31	+33
Commercial	142	87	116	98	− 7
Industrial	1,400	975	1,200	770	−17
Water sales revenue—*$/mil gal*	210	196	300	290	+44
Public fire service charge—*$/hydrant/yr.*	32	30	42	40	+32
Depreciation reserves—*$/cap.*	17	16	16	14	− 9
Surplus in reserve—*$/cap.*	12	5	8	7	−12
Funded debt—*$/cap.*	33	29	28	26	−13
Book value—*$/cap.*	82	76	68	62	−18

* See also Tables 31 and 33.
† Weighted according to treatment type and volume group.

Privately Owned Utilities

The 1955 survey included returns from 59 privately owned utilities representing every population and volume group, all treatment types, and every geographic region, although Pennsylvania, New York, and the New England area were most heavily represented. As a group, private companies exhibited substantial physical and

financial differences from publicly owned utilities.

Table 31 (previously referred to) summarizes the sources of the revenue dollar and its ultimate disposition for privately owned, publicly owned (except Wisconsin), and publicly owned Wisconsin utilities. Residential sales income was the largest single revenue source for each of the three groups,

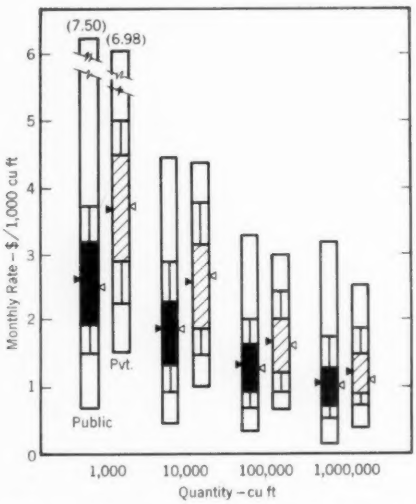

Fig. 12. Rates of Publicly and Privately Owned Utilities

The left-hand bar in each pair applies to publicly owned utilities; the right-hand bar, to privately owned.

but particularly so for private companies. Distribution of funds available after operating costs and taxes was more varied, with the pattern for Wisconsin resembling that for privately owned utilities in some respects (less debt service, lower capital expense). For privately owned utilities, both debt service and capital expense were less than for publicly owned utilities; the difference was made up in part by heavier dollar allocation to reserves and also by dividends to stockholders substantially exceeding the contributions made by publicly owned utilities to general funds.

Physical and some further financial differences between publicly and privately owned utilities are summarized in Table 32, which evaluates these differences in terms of weighted percentages. In per capita production, privately owned utilities were 14 per cent lower; the difference in percentage of production sold is not significant.

With respect to physical system, some interesting differences were noted. Private companies were about 10 per cent lower in main mileage and in hydrants per mile of main; they were one-third lower in distribution storage. As to employees per 1,000 population, private companies as a group reported only 5 for every 6 employed by publicly owned utilities. Part of this difference may be accounted for by clerical or other public employees who spend part or all of their time in inspection, accounting, or other work not directly related to the water department.

With regard to reserve funds and funded debt, private companies were less extended in either direction, and were probably in a position comparable to that of publicly owned utilities, disregarding stockholders' equity.

Analysis of total book value indicated an appreciable difference, which was found to occur chiefly in supply and treatment works, as the book value of the distribution system alone was essentially the same for both publicly and privately owned utilities.

In the area of rates and earnings (see Table 33 for 1955), privately owned utilities were heavily on the plus side of the comparison. Monthly rate

schedules for private companies were consistently higher (Fig. 12). The difference ranged from 52 per cent at the 1,000-cu ft step to 22 per cent at dustrial service revenue was less on this basis than for publicly owned utilities because of substantially lower sales volume per account.

TABLE 33

Comparison of 1945, 1950, and 1955 Survey Data *

Item	1945		1950		1955	
	Public	Private	Public	Private	Public	Private
Production—*gpcd*	126	117	139	124	139	120
Distribution*—*gpcd*	99	103	111	99	121	103
Per cent sold	81	83	83	83	84	86
Monthly rates—$						
1,000 cu ft	1.89	2.46	2.23	2.82	2.62	3.70
10,000 cu ft	14.10	16.70	16.80	20.10	19.00	25.90
100,000 cu ft	93	118	117	128	134	166
1,000,000 cu ft	785	945	935	925	1,060	1,220
Min. charge—$			1.00	1.00	1.20	1.52
Allowance on min.—*cu ft*			490	395	430	360
Revenue						
Water sales, per residential service—*$/yr.*	17	21	20	24	25	33
Total—*$/cap.*	5.98	7.65	7.94	9.20	10.65	12.16
Total—*$/mil gal*†	151	182	182	234	228	330
Expense—*$/mil gal*†						
Op. and maint.	76	70	98	103	118	136
Miscellaneous	‡	‡	3	2	3	3
Taxes	1	39	2	53	2	84
Total	77	109	103	158	123	223
Op. and maint.—*$/cap.*	3.01	3.22	4.33	3.90	5.50	4.88
Earnings—*$/mil gal*†§	74	73	79	76	105	107
Book value—*$/cap.*	52	60	66	63	82	68
Debt—*$/cap.*	17	28	25	28	33	28

* Mean values throughout. "Distribution" includes sales and free for 1955, but sales alone for 1945 and 1950.
† Per million gallons produced.
‡ Included above.
§ Total revenue less total expense as above.

1,000,000 cu ft. With these higher rate schedules, privately owned utilities reported 44 per cent more water sales revenue per million gallons produced. Revenue per residential service was 33 per cent higher. Commercial and in-

Operation and maintenance costs per million gallons were 19 per cent higher for privately owned utilities, while miscellaneous expense was the same. Taxes represented the key difference. Analysis of the private companies' tax

bill (approximately $80 per million gallons) revealed the following division: local taxes, 34 per cent; state, 11 per cent; and federal, 55 per cent, or $45 per million gallons for this portion alone.

The above expense items totaled approximately $100 per million gallons (or 85 per cent) more than for public utilities of similar size and character.

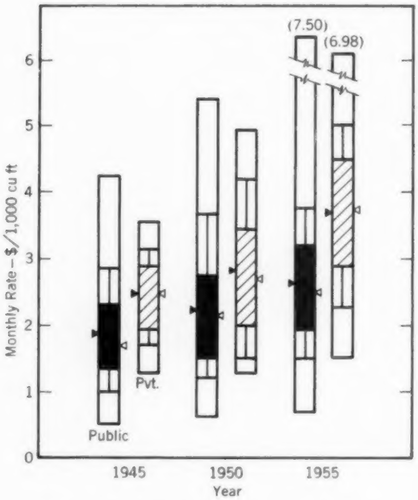

Fig. 13. Comparison of Rates for First 1,000 cu ft, 1945–55

The left-hand bar in each pair applies to publicly owned utilities; the right-hand bar, to privately owned.

1945–55 Comparisons

Reference is again made to Table 33, which contains a summary of rates, revenue, and expense items for publicly and privately owned utilities in the three AWWA data surveys (1945, 1950, 1955). Some of the trends indicated are particularly significant, not only as percentages, but in terms of dollars, since utility growth must still be financed by dollars rather than percentage points.

In 1945 privately owned utilities were operating with rate schedules about 30 per cent higher than those of publicly owned utilities. In the ensuing 10 years, the latter's rates increased about 40 per cent, by fairly equal steps in each 5-year period. Privately owned utilities, on the other hand, raised their rates approximately 60 per cent over this 10-year period, with the increase from 1950 to 1955 being almost double that for the first 5 years. As a result, the lower steps of private-company rate schedules in 1955 were 40–50 per cent above those for publicly owned utilities (Fig. 13).

Private companies allowed 11 per cent less water than publicly owned utilities on the minimum bill in 1955, while collecting 33 per cent higher minimum charges. Although both had reduced the water allowance about 5 per cent over the 1950–55 period, private companies increased minimum charges 46 per cent in the same period, compared to only 17 per cent for publicly owned utilities.

How were these increases reflected in revenue? From 1945 to 1955 publicly owned utilities reported an overall revenue increase, in round figures, of $75 per million gallons, while private companies achieved an increase of $150—twice as great. The amount of gain by private companies during the second 5-year period was approximately twice that during the first 5 years, coinciding with the pattern of their rate increases. For 1955, private companies reported revenue per million gallons at a level about 45 per cent above that for publicly owned utili-

ties, again matching the difference in rates.

Before concluding that private water companies as a group were amassing great wealth, a look at the expense side of the ledger is in order. Over the 1945–55 period, publicly owned utilities experienced an increase of $40 per million gallons in operation and maintenance costs, while this increase for private companies amounted to $65. For both, the increments during each 5-year period were reasonably alike. Taxes, however, increased $45 per million gallons for privately owned utilities while remaining nominal for publicly owned.

Trends

During the 1945–50 period, the net result of these increases in rates, revenue, and costs was a gain in earnings on the order of $5 per million gallons for both publicly and privately owned utilities. This represented a gain of about 7 per cent in funds available for depreciation, debt service, capital improvements, and reserves—in a period marked by a 65 per cent jump in water works construction costs.

During the 1950–55 period, even more vigorous rate and revenue increases produced a net gain in available funds (after operating expenses

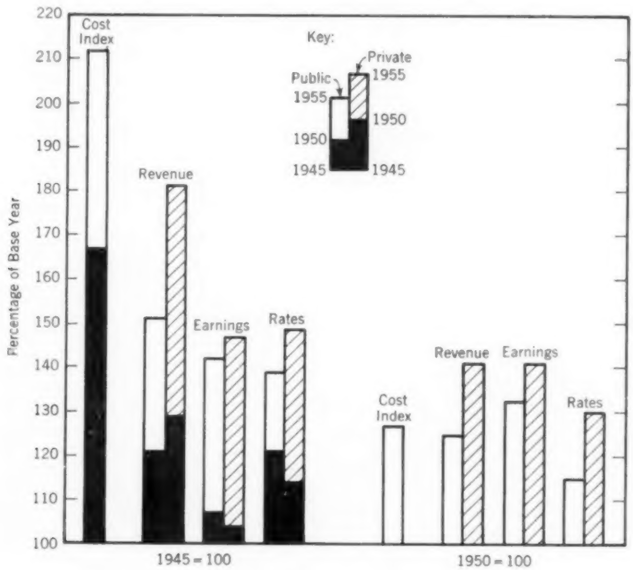

Fig. 14. Cost and Revenue Trends, 1945–55

In the group of bars at the left, 1950 and 1955 mean values for the items shown have been converted into percentages of the mean values for 1945. In the group at the right, 1955 mean values are given as percentages of 1950 mean values. The cost index bars are composites of several construction cost indexes, as explained in the text.

and taxes) of about $25 per million gallons (30 per cent) for publicly owned utilities and about $30 (40 per cent) for privately owned utilities. It is worth noting that, in seeking to increase earnings, privately owned utilities are faced with the added problem of diminution of any such increase by the higher taxes automatically incurred.

Figure 14 relates the 1945–55 trends in revenue and earnings to a composite index of water works construction costs.* The failure of water works revenue and earnings, for both publicly and privately owned utilities, to match construction cost rises since 1945 is clearly apparent from the group of bars at the left, which use 1945 as the base year. A more optimistic trend, however, is exhibited by the bars at the right, which use 1950 as the base year.

It may be concluded that, since 1950, publicly owned utility earnings have been keeping up with cost trends, while privately owned utilities have been doing mildly better. But both have still to make up the considerable ground lost during 1945–50. If the relationship between costs and earnings in 1945 was satisfactory (and there is no reason to believe it was better than that), further rate increases to restore that position appear mandatory. It should be recalled that, as defined in this survey and analysis, it is "earnings" which provide the funds for the expansion of facilities required by continually increasing water demands.

* The indexes used were: Weber, Fick & Wilson Water Works Indexes, for two types of plants (additional data provided by H. H. Fick); Handy-Whitman Index of Water Utility Construction Costs, for small treatment plants and for distribution mains; and *Engineering News-Record* 20-Cities Common Labor Index, for building and heavy construction.

Acknowledgment

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Editor's Note

In preparing this analysis, the authors made up a great many more tabulations (and charts) from the survey data than could be printed here. Some of these are extensions of tables printed in summary form in this analysis; others are different types of breakdowns, or are more detailed, or cover items for which no tabulation was given above (most of this additional material concerns Survey Tables 2–4). Persons doing research work on the 1955 survey may wish to consult the editor about the availability of such additional analytic tabulations on specific points of interest.

Summary of 1955 USPHS Survey of Treatment Facilities in Communities of 25,000 and Over

Ralph Porges

A contribution to the Journal by Ralph Porges, Sr. San. Engr., Robert A. Taft San. Engr. Center, USPHS, Cincinnati, Ohio.

STATISTICS are presumably dry, yet when applied to the vigorous and growing water supply industry they reveal many interesting facets. Statistics are essential to establish norms of water supply practices, to gage progress in the art and science of water treatment, and to detect the development and acceptance of new methods. Evaluation of data is also essential as a guide for future water supply facility design and water treatment practice.

In the past, extended periods of data paucity have made it extremely difficult adequately to depict the conditions existing during those times. *Water Works Practice* (*1*) after the 1895 entry states, "Here, complete half-decade records stop. . . . " Water treatment inventories, however, compiled by the USPHS for the years 1910 and 1915 have recently been uncovered. The need for inventory data was apparent to state health departments in the late 1920's, and joint effort with the USPHS resulted in 1931 in an inventory report by the Committee on Water Purification and Treatment, Conference of State Sanitary Engineers (*2*). The USPHS, at the request of the conference, continued this activity and published a summary of 1940 data (*3*) and a complete water–sewage inventory for 1945 (*4*). The most comprehensive water inventory to date (for the year 1948) was analyzed in the 1953 report, "Statistical Summary of Water Supply and Treatment Practices in the United States" (*5*).

Water resource planning, necessitated by increasing water demands and current water shortages, has continued to focus interest on water supply information. Because of limited administrative resources, however, recent compilations have been restricted to the larger cities, which nonetheless represent a large majority of the population served by public water supplies. In 1953, Picton (*6*) of the Department of Commerce reported on communities of 25,000 population and over, with primary concern on facility adequacy. The following year, the USPHS issued two inventories on water supply facilities and water treatment practices, one limited to communities of 25,000 population and over (*7*) and the other encompassing all water supplies serving populations of 10,000 and greater, plus a 40 per cent sample of communities of between 5,000 and 10,000 population (*8*). A subsequent inventory was issued for municipal water facilities of communities of 25,000 population and over (*9*) effective Dec. 31, 1955, which recorded statistics regarding water sources, transmission capacities, treatment facilities, distribution systems, adequacy of distribution and improvements needed. This article summarizes

State	Total No. of Entries	1950 Census Population *1,000's*	Est. Population Served *1,000's*	Avg. Daily Output *mgd*	Avg. Consumption *gpcd*	No. of Services *1,000's*	No. of Meters *1,000's*
Alabama	7	723	999	105.50	106	206	206
Arizona	2	152	323	54.48	169	79	79
Arkansas	5	261	364	29.39	81	73	73
California	46	5,595	8,118	1,207.11	149	1,797	1,696
Colorado	3	525	784	130.00	166	185	45
Connecticut	26	1,348	1,684	222.82	132	333	262
Delaware	1	110	149	25.00	168	36	35
District of Columbia	1	802	1,103	163.00	148	131	124
Florida	15	1,064	1,750	208.75	119	398	396
Georgia	10	885	1,453	177.53	122	299	286
Idaho	2	61	84	13.43	160	22	22
Illinois	27	4,940	6,024	1,236.11	205	871	523
Indiana	19	1,549	1,794	245.97	137	444	433
Iowa	13	744	843	92.85	110	221	207
Kansas	5	436	645	81.15	126	150	150
Kentucky	7	618	950	118.32	125	193	191
Louisiana	8	972	1,286	152.37	118	275	273
Maine	5	186	244	31.93	131	53	29
Maryland	4	1,024	1,870	252.32	135	430	296
Massachusetts	37	3,079	3,276	378.86	116	582	551
Michigan	20	3,118	4,079	691.83	170	702	678
Minnesota	6	1,021	1,065	114.97	108	232	229
Mississippi	7	290	382	43.60	114	78	74
Missouri	10	1,998	2,541	347.00	137	493	375
Montana	3	104	168	34.00	202	39	16
Nebraska	2	350	438	83.18	190	103	108
Nevada	2	65	102	37.70	370	30	*
New Hampshire	3	145	148	18.25	123	29	25
New Jersey	44	2,469	3,522	495.12	141	558	495
New Mexico	3	151	242	42.69	176	55	55
New York	44	10,626	11,686	1,548.29	132	1,453	704
North Carolina	11	662	848	92.46	109	205	202
North Dakota	2	65	72	7.90	110	16	16
Ohio	35	3,922	5,018	806.98	161	1,140	1,118
Oklahoma	7	579	754	100.36	133	213	198
Oregon	3	453	668	80.30	120	189	186
Pennsylvania	39	4,279	6,575	931.45	142	1,507	1,094
Rhode Island	9	552	716	76.11	106	138	136
South Carolina	4	252	484	53.57	111	92	92
South Dakota	2	78	112	15.50	138	24	24
Tennessee	7	914	1,286	159.85	124	306	297
Texas	24	2,932	4,016	512.88	128	934	937
Utah	3	268	327	68.70	210	76	76
Vermont	1	33	39	2.90	75	7	8
Virginia	11	999	1,362	134.27	99	274	264
Washington	8	949	1,216	364.10	299	297	280
West Virginia	7	335	478	55.37	116	118	116
Wisconsin	18	1,367	1,552	252.90	163	375	323
Wyoming	2	56	66	14.30	218	17	17
Totals	580	64,106	83,704	12,113.52	145	16,478	14,020

* 27 meters.

Summary of Water Facilities in Communities of 25,000 and Over, 1955

Percentage Metered					Ownership				Source of Supply						Laboratory Control			
									Ground		Surface		Both					
Unreported	Less than 50%	50–90%	90–99%	Over 99%	Public	Private	Both	Unreported	No. of Utilities	Est. Pop. Served *1,000's*	No. of Utilities	Est. Pop. Served *1,000's*	No. of Utilities	Est. Pop. Served *1,000's*	Bacteriological	Chemical	Both	None and Unreported
No. of Utilities																		
			2	5	6	1			2	202	5	797			2	3		2
			1	1	2				1	93			1	230		1	1	
				5	3	2			1	43	3	234	1	87			5	
1	5		3	37	35	9		2	11	646	19	4,017	16	3,454	5		22	19
	2	1			3						1	622	2	162		1	1	1
4	3	6	3	10	14	10		2			20	1,290	6	393	2	1	12	11
			1		1						1	149					1	
			1		1						1	1,103					1	
			1	14	15				11	1,312	2	316	2	122	3		9	3
		1	1	8	10				1	44	8	1,209	1	200			9	1
				2	1	1			1	55			1	29				2†
3	1	1	5	17	19	7		1	8	564	18	5,389	1	72	4	1	16	6
1		1	3	14	12	7			5	271	8	670	6	853	1	1	16	1
	1	2	2	8	10	3			6	308	6	316	1	219	5	1	5	2
				5	3	1	1		3	320	1	205	1	120			4	1
			1	6	6	1			1	48	6	902				1	6	
			1	7	6	2			4	337	4	949				1	6	1
1	1	3			4	1					5	244					4	1
		2		2	4						3	1,817	1	53			4	
	3	1	11	22	37				1	97	34	3,112	2	67	1	1	20	15†
	1	1	3	15	20				5	385	14	3,634	1	60	2		17	1
			1	5	6				2	60	3	670	1	335	1		3	2
		1	3	3	7				4	157	2	175	1	50		1	1	5
	1		4	5	3	7			1	35	8	2,414	1	92	2	2	6	
	2		1		2	2					3	168			1		2	
				2	2				1	125	1	313					1	1
	2				1	1							2	102				2
		1	2		2	1					1	87	2	61				3
22	1	2	5	14	14	11		19	7	409	23	2,479	14	634		1	35	8
				3	2	1			2	208			1	34			2	1
3	11	2	7	21	31	10		3	12	1,086	30	2,584	2	8,017	6		30	8
		1		10	10	1					11	848					11	
				2	2						2	72					2	
5	1	2	2	25	32	3			7	710	24	3,646	4	662	3	1	30	1
	1		1	5	7				2	70	4	393	1	290		2	3	2
			1	2	3						3	668			1		1	1
5	7	4	3	20	21	16		2	2	124	32	6,178	5	274	1	4	25	9
1			2	6	8	1					5	603	4	113		1	6	2
			1	3	4						4	484				1	3	
				2	2				2	112						1		1
			1	6	6	1			2	490	4	756	1	40	1		6	
			1	23	23		1		6	941	11	1,784	7	1,291	1	1	16	6
				3	3								3	327			1	2†
				1	1						1	38			1			
		1		10	10	1					10	1,262	1	100	1	2	7	1
	2	1	2	3	8				2	236	4	885	2	95	2		3	3
			2	5	5	2			1	60	5	356	1	62			7	
		5	7	6	16	2			11	493	7	1,059			2	2	9	5
				2	2				1	33			1	33		1		1
46	45	39	85	365	445	104	2	29	126	10,074	357	54,897	97	18,733	48	32	369	131

† One reported no control.

TABLE 2

State	Filters					
	Total		Rapid Sand		Slow Sand	
	No. of Utilities	Est. Pop. Served *1,000's*	No. of Utilities	Est. Pop. Served *1,000's*	No. of Utilities	Est. Pop. Served *1,000's*
Alabama	4	797	4	797		
Arizona	2	153	2	153		
Arkansas	4	363	3	321		
California	18	2,694	13	2,100		
Colorado	6	543	4	295	1	124
Connecticut	13	988	9	289	4	699
Delaware	1	149	1	149		
District of Columbia	2	1,103	1	551	1	552
Florida	12	1,337	11	1,172		
Georgia	9	1,309	9	1,034		
Idaho						
Illinois	16	2,583	15	2,369		
Indiana	18	1,386	16	1,340		
Iowa	8	565	8	565		
Kansas	4	610	4	610		
Kentucky	7	950	7	950		
Louisiana	8	1,060	7	975		
Maine	2	63	2	63		
Maryland	5	1,844	4	1,795	1	24
Massachusetts	7	471	4	253	3	218
Michigan	11	3,774	11	3,723		
Minnesota	4	1,005	4	1,005		
Mississippi	4	257	4	257		
Missouri	9	2,506	9	2,506		
Montana	2	115	2	88		
Nebraska	2	438	2	438		
Nevada						
New Hampshire						
New Jersey	16	1,582	9	1,337		
New Mexico						
New York	24	2,948	16	2,134	4	185
North Carolina	10	773	10	756		
North Dakota	2	72	2	72		
Ohio	29	4,645	25	4,473		
Oklahoma	5	683	3	356	1	19
Oregon	1	62	1	62		
Pennsylvania	31	5,300	24	3,048	3	1,725
Rhode Island	7	620	6	603	1	8
South Carolina	4	324	4	230		
South Dakota	1	60				
Tennessee	6	1,226	6	1,226		
Texas	21	2,960	18	2,691		
Utah						
Vermont	1	38	1	39		
Virginia	14	1,329	11	1,125	1	36
Washington						
West Virginia	7	478	6	355		
Wisconsin	9	1,165	7	1,091	1	36
Wyoming	1	33	1	33		
Totals	367	51,361	306	43,428	21	3,626

Filtration and Miscellaneous Treatment in Communities of 25,000 and Over, 1955

Filters				Disinfection Only or With Miscellaneous Treatment		Other or Unreported Treatment		Untreated	
Pressure		Other and Unreported							
No. of Utilities	Est. Pop. Served *1,000's*	No. of Utilities	Est. Pop. Served *1,000's*	No. of Utilities	Est. Pop. Served *1,000's*	No. of Utilities	Est. Pop. Served *1,000's*	No. of Utilities	Est. Pop. Served *1,000's*
				2	202				
				4	170				
		1	43						
5	593			20	4,795			12	629
		1	124	5	241				
				11	696				
		1	165	4	413				
1	275			2	144				
				2	84				
1	140	2	74	6	3,441				
1	14	1	32	6	409				
				5	278				
				1	35				
		2	85	2	226				
				2	181				
		1	24	1	27				
				16	2,805				
		1	51	5	305				
				2	60				
				3	125				
				1	35				
		1	27	1	53				
				2	78			1	23
				4	148				
8	245			13	1,815	1	25	1	100
				2	209			1	33
3	444	1	185	10	8,337	6	326	2	75
		1	17	1	75				
		2	171	5	373				
		2	309	2	70				
				2	606				
		7	527	11	1,275				
1	8			3	96				
		2	95	1	160				
		1	60	1	52				
				2	60				
		4	269	8	1,056				
				7	327				
2	90	1	78	1	33				
				8	1,216				
		3	124						
		1	38	8	387				
				1	33				
22	1,809	36	2,498	193	31,131	7	351	17	860

TABLE 3

State	Utilities With Disinfection		Treatment					
			Softening		Iron & Manganese Removal		Aeration	
	No. of Utilities	Est. Pop. Served *1,000's*	No. of Utilities	Est. Pop. Served *1,000's*	No. of Utilities	Est. Pop. Served *1,000's*	No. of Utilities	Est. Pop. Served *1,000's*
Alabama	6	999					1	140
Arizona	6	323						
Arkansas	4	364			1	43	1	43
California	38	7,489	3	837			9	926
Colorado	11	784					1	124
Connecticut	24	1,684					11	661
Delaware	1	149						
District of Columbia	2	1,103						
Florida	15	1,750	8	1,151	3	122	11	917
Georgia	11	1,453						
Idaho	2	84						
Illinois	22	6,025	8	503	6	430	3	173
Indiana	24	1,794	2	188	5	220	7	312
Iowa	13	843	4	383	1	30	3	99
Kansas	5	645	3	405	1	35	3	405
Kentucky	7	950	1	48			3	190
Louisiana	10	1,286	3	670	2	111	4	257
Maine	4	244					1	33
Maryland	6	1,870	1	49			2	467
Massachusetts	22	3,192			1	49	5	313
Michigan	16	4,079	5	543	1	48	1	48
Minnesota	6	1,065	2	868			1	335
Missisippi	7	382			1	32	2	62
Missouri	10	2,541	6	2,280			2	127
Montana	3	168						
Nebraska	2	4,038			1	125	1	125
Nevada	2	79						
New Hampshire	4	148						
New Jersey	27	3,301			5	147	9	517
New Mexico	2	209						
New York	33	11,010			5	1,187	16	9,345
North Carolina	11	848						
North Dakota	2	72	2	72			2	72
Ohio	30	5,018	14	1,892	1	40	5	248
Oklahoma	7	754	2	327				
Oregon	3	668						
Pennsylvania	42	6,575	4	547	4	364	4	405
Rhode Island	10	716			1	16	6	600
South Carolina	5	484					1	120
South Dakota	2	112			1	60		
Tennessee	7	836			1	450	3	794
Texas	29	4,016	8	689	1	200	10	560
Utah	7	327						
Vermont	1	38						
Virginia	15	1,362			2	67	8	696
Washington	8	1,216						
West Virginia	7	478	1	42	1	60	4	351
Wisconsin	17	1,552	1	38	3	106	5	284
Wyoming	2	66					1	33
Totals	550	81,588	78	11,533	48	3,942	146	19,782

Treatment Methods Other Than Filtration, in Communities of 25,000 and Over, 1955

Treatment						No. of Utilities Reporting Natural Fluorides		
Taste & Odor Control		Corrosion Correction		Fluoridation				
No. of Utilities	Est. Pop. Served *1,000's*	No. of Utilities	Est. Pop. Served *1,000's*	No. of Utilities	Est. Pop. Served *1,000's*	Less Than 0.5 ppm	0.5–0.9 ppm	More Than 0.9 ppm
		4	797	1	70	1		
2	153							
3	321	2	243	1	201	1		
10	1,497	14	1,479	2	1,541	6	3	
4	498			1	124	1		4
3	110	13	952	1	85			
2	1,103	2	1,103	2	1,103			
4	493	5	256	4	701	6	1	
3	351	9	1,309	4	288	1		
						1	1	
11	5,287	4	4,648	5	286	3		2
12	1,140	2	165	9	795	7	1	
7	535	3	384	4	252	5	3	1
3	325	2	285			1	1	
6	902	1	52	4	740			
3	232	5	345			4		1
1	30	1	30					
2	75	5	1,844	6	1,870	5		
2	154	5	302	1	31	2		
10	3,655	4	286	9	640	7		
3	670	1	25	1	335	1		
2	190	1	140	1	50	1		
3	166	1	750					1
2	115	1	60			2	1	
1	313						1	
1	55					1		
		1	14	2	28			
8	1,342	10	1,646	4	100			
		1	34			1	2	
12	864	11	1,070	8	616			
8	680	11	848	6	473	4		
2	72	2	72	1	41	2		
20	3,925	13	2,049	5	526	12	2	
1	290	2	328	3	576	2		2
16	1,815	16	2,400	5	909	2		
4	212	7	268	6	580	1		
4	324	5	484			1		
1	250	5	512	2	282	1		
12	2,427	6	456	3	309	8	2	4
		1	47					
				1	39			
10	1,103	14	1,329	11	1,019	3		
1	648	1	39					
6	418	5	306	6	436	3		
6	1,059			11	1,283	2		1
						1		1
211	33,799	196	27,357	130	16,329	99	18	17

the 1955 inventory, presents some conclusions, and depicts possible trends.

Collection of Data

The usual method of state health department–USPHS cooperation was utilized for collection of the data. The state health departments secured the information from the local facilities and transmitted it to the Department of Health, Education, and Welfare, where it received final review. Doubtful items were referred back to the state health departments for ultimate resolution. It is recognized that there are omissions and that errors, no doubt, still persist. It is believed, however, that these errors are of a minor nature and probably do not effect the overall accuracy of the results.

TABLE 4

Classification of Entries

Items	Utilities	
	No.	%
Total entries	580	100
Sources of supply		
Surface	357	61.6
Ground	126	21.7
Both ground and surface	97	16.7
Ownership		
Public	445	76.7
Private	104	18.0
Both	2	0.3
Unreported	29	5.0
Laboratory control		
Bacteriological	48	8.3
Chemical	32	5.5
Both	369	63.6
None or unreported	131	22.6
Metering		
Less than 50%	45	7.8
50–90%	39	6.7
90–99%	85	14.7
Over 99%	365	62.9
Unreported	46	7.9

Prior to analysis, the data were scanned for possible duplication where several communities are served by one system or where several systems are interrelated. To interpret the data properly, it was necessary to have detailed knowledge regarding the interrelationship of metropolitan water supply as it occurs in eastern Massachusetts, Southern California, northern New Jersey, and elsewhere. For example, the Metropolitan District Commission of Massachusetts serves eighteen inventoried communities, which individually reported a total population served by district water of 1,716,000. This figure is in close agreement with the 1,812,000 reported by the commission. The average use of district water reported by the eighteen communities totalled 202 mgd, compared to 197 mgd reported by the commission, again a close check. To eliminate duplication in the state total, the report of the commission replaced the eighteen community reports.

If a rational breakdown of data was not indicated, it was arbitrarily assumed that one-half of the supply was in one category and one-half in the other. Data apportionment between two functions as slow-sand and rapid-sand filters in a single plant results in more filter items than plants. Thus, the number of filters does not necessarily total the number of plants, although the population served will be additive.

It was essential in some categories to adjust the data to account for missing entries. Statistics, both for the 1950 census and for estimated population served, were essentially complete. The numbers of services and meters were adjusted to provide for those few instances where figures were not reported. The average daily output was

recorded in practically all instances; other rates were adjusted, as were plant capacity and overload data. The breakdown of the average daily output into its components—domestic, commercial, industrial, public, and other—was reported in only about one-fourth of the cases, so analysis was restricted to the reported entries.

Presentation of Data

Inventory data are summarized by states in Tables 1–3. Table 1 shows population statistics, average daily consumption, services, and meters including a breakdown by percentage metering, ownership, source of supply, and laboratory control. Table 2 summarizes treatment by filtration and miscellaneous treatment and includes that small portion without treatment. Table 3 itemizes the treatment methods other than filtration.

Tables 4–8 illustrate the national statistics and provide a basis for comparison with previous records by which developing trends may be detected. Table 4 includes sources of supply, ownership, laboratory control, and a breakdown by percentage metered. Table 5 contains data on types of filters, disinfection practiced without filters, and untreated supplies. Table 6 presents plant functions other than filtration. Table 7 records water use and plant production including average daily output; maximum hour, day, and month; and average daily use by domestic, commercial, industrial, and public and other consumers. Table 8 depicts an evaluation of water sources, plant capacity, ability of distribution systems to meet maximum demand, and improvements needed.

As of Dec. 31, 1955, there were 580 entries serving populations of 25,000 and over. A community entry may pertain to a municipal water supply, a water system serving several communities, or a private water company. The total 1950 census population of communities within this group was 64,106,456.

The estimated population served as of Dec. 31, 1955, reached 83,704,000, an increase of nearly 3,000,000 over that reported in 1954 (*10*). This increase is about equal to the population gain in the United States for the year (*11*). It is estimated that over 17,000

TABLE 5

Types of Treatment Plants and Miscellaneous Operations

Items	Plants		Est. Pop. Served	
	No.	%	No. *1,000's*	%
No. of treatment plants	567	100.0	82,844	99.0*
Filter plants	367	64.7	51,361	61.4
Rapid sand	306†		43,428	51.9
Slow sand	21†		3,626	4.3
Pressure	22†		1,809	2.2
Others and unreported	36†		2,498	3.0
Disinfection only or with misc. treatment	193	34.1	31,131	37.2
Other or unreported treatment	7	1.2	351	0.4
Untreated (completely or partially)	17		860	1.0

* Percentage of estimated population served by all the 580 utilities surveyed (83,704,000).

† Not additive, since some plants have more than one type of filter.

TABLE 6

Plant Functions Other Than Filtration

Items	Plants		Est. Pop. Served	
	No.	%	No. *1,000's*	%
No. of treatment plants	567	100.0	82,844	99.0*
Disinfection	550	97.0	81,588	97.5
Softening	78	13.8	11,533	13.8
Iron and manganese removal	48	8.5	3,942	4.7
Chemical taste and odor control	211	37.2	33,799	40.4
Corrosion correction	196	34.6	27,357	32.7
Fluoridation	130	22.9	16,329	19.5
Natural fluorides reported	134			
Less than 0.5 ppm	99			
0.5–0.9 ppm	18			
More than 0.9 ppm	17			

* Percentage of estimated population served by all the 580 utilities surveyed (83,704,000).

communities in the United States have public water systems serving a total of approximately 118,000,000 people. Thus, the population served included in this 1955 inventory is estimated as 71 per cent of the total served by community water supplies in the United States.

Surface water sources supplied 65.6 per cent of the population served, ground sources 12.0 per cent and both ground and surface sources 22.4 per cent (Table 4). There have been no radical changes in these percentages over the past 8 years (*5* and *10*).

Ownership statistics indicate that 76.7 per cent were municipally operated, 18.0 per cent privately owned, and 0.3 per cent combine public and private ownership; unreported were 5.0 per cent. Unreported entries dropped 1.1 per cent over 1954, and private supplies increased 0.8 per cent. Resolution of the unreported entries may increase the percentage of private supplies.

Both bacteriological and chemical analyses were conducted at 63.6 per cent of the plants, which is an increase of 6.3 per cent over 1954. Slight decreases were noted in plants practicing only chemical or bacteriological control; those reporting no control or not reporting dropped 3.6 per cent, to 22.6 per cent.

The water systems reported 16,-478,000 services and 14,020,000 meters. These figures indicate that an average of about five persons were served per service and about 85 per cent of the services were metered. Table 4 breaks down metering figures into percentage groups. Those communities with minimal metering might realize a per capita use reduction averaging 25 per cent with complete metering (*12*).

Table 5 presents a breakdown of the various types of filters employed in water treatment plants. Also shown are those systems using chlorination without filtration and that small portion served without treatment.

Of the 567 treatment plants serving 82,844,000 or 99.0 per cent of the population served, 367 or 64.7 per cent were filtration plants, the majority—306—being rapid-sand installations. Slow sand, pressure, and other filters amounted to 21, 22, and 36, respectively. Disinfection without filtration was practiced by 193, or 34.1 per cent, of the plants.

TABLE 7

Water Use and Plant Output

Classification	Output	
	%	*gpcd*
580 entries serving 83,704,000		
Avg. daily output	100	145
Max. hour—191 entries	257	373
Max. day—512 entries	162	235
Max. month—502 entries	140	203
206 entries reporting breakdown		
Avg. daily output	100.0	145
Domestic	40.8	59
Commercial	18.0	26
Industrial	24.5	36
Public and other	16.7	24

Because of the small number of untreated supplies, a separate table on this item was not developed. Four states reported twelve untreated ground water supplies serving 697,900 people; in two states, five supplies secured from both surface and ground sources were reported as both treated and untreated. The surface portion was treated in all instances; the untreated ground portion supplied a population of about 162,600. Untreated water supplies are diminishing.

Plant functions other than filtration are shown in Table 6. Of 99.0 per cent of the population served with treated water, 97.5 per cent obtained water that was chlorinated, 13.8 per cent softened water, 4.7 per cent water treated for iron and manganese removal, 40.4 per cent for taste and odor control, 32.7 per cent for corrosion correction, and 19.5 per cent fluoridated. There have been increases in the above treatment practices in recent years. Inferior raw-water quality as result of increased pollution and the need to tap waters of lower quality, coupled with demand for better water, could be influencing factors.

As of Dec. 31, 1955, fluoridated water supplies were used by 1,274 communities serving a total population of 24,401,000 (*13*). Ten years ago only 232,000 people in three communities had fluoridated supplies. A gain of twelve plants has been recorded in the past year. Natural fluorides were reported by 134 entries.

A heated discussion can be instigated among water works personnel by raising the question, "What is the average daily per capita consumption and how fast is it increasing?" Over the nation, a wide fluctuation in unit values exists. For example, Everett and Bellingham, Wash., reported for 1955 an average per capita consumption of 2,180 and 1,320 gpd respectively. Tacoma, Wash., reported 338 gpcd, but the domestic portion was only 65 gpcd. Obviously, these extremely high values are the result of industrial demands. Each case, then, presents its own unique problem, yet overall statistics as shown in Table 7, must play a part in water resource planning and development.

Increasing use of household equipment as dishwashers and garbage grinders does not necessarily mean increasing the demand for water. This equipment replaces functions that may have been equally or more wasteful of water. At Jasper, Ind. (*14*), where studies of rates of water usage before and after installation of grinders were made, no noticeable change in usage by residential consumers was recorded. Another study (*15*) at Tucson, Ariz., showed that the sewer line with household grinders averages 4.2 gpcd less than the line without garbage grinders.

Among the population group 25,000 and over, the average daily per capita consumption in 1955 was 145 gal (Table 7). This value may be compared to 149 gal in 1948 (*5*), 148 gal in 1953 (*6*), and 149 gal in 1954 (*10*). In recent years, no distinct trend has appeared. A report (*12*) in 1954 covering communities of 5,000 population and over gave the average daily per capita consumption of 143 gal. It is estimated, considering all water supplies in the United States, that the 1955 consumption per capita would probably fall between 140 and 143 gpd.

With all rates of usage converted to million gallons per day, the maximum hour was reported as 257 per cent of the average day, maximum day as 162 per cent of the average, and maximum month as 140 per cent of the average. Close agreement was observed with the 1954 report (*10*), which indicated the maximum hour as 231 per cent and maximum day as 163 per cent of the average.

A total of 206 community entries reported on the indicated water usage segments. These averaged 40.8 per cent or 59 gpcd for domestic usage, 18.0 per cent or 26 gpcd for commercial purposes, 24.5 per cent or 36 gpcd for industrial needs, and 16.7 per cent or 24 gpcd for public and other uses. These values check rather closely with the 1954 evaluations of 42.8 per cent (64 gpcd) for domestic, 18.9 per cent

(28 gpcd) for commercial, 24.9 per cent (37 gpcd) for industrial and 13.4 per cent (20 gpcd) for public and other uses. It will be noted that the combined industrial and commercial demand upon municipal water supplies in 1955 amounted to 42.5 per cent. A discussion of industry's stake in public water supplies is of interest (*16*).

Table 8 shows an evaluation of the various water facility components and provides a summary of the needed improvements. The results show that 203 or 46.9 per cent of the sources had safe yields exceeding 300 per cent of the average daily demand, 84 or 19.4 per cent could yield safely 200–300 per cent of the daily needs, 63 or 14.5 per cent from 150 to 200 per cent of daily needs, and 64 or 14.8 per cent from 100 to 150 per cent of the average daily demand. Nineteen or 4.4 per cent could not supply safely the average daily requirements. These data point to the need for basic water resource planning especially when considering that the maximum daily demand was 162 per cent of the average daily output. A water resource study in the Missouri River Basin (*17*) showed that over 14 per cent of the communities had inadequate water supplies in 1955 and that by 1975 this figure might increase to 35 per cent. These inadequacies did not consider water quality reported by some 23 per cent in the Missouri Basin as being undesirable in its chemical and physical characteristics.

A study was made of 404 entries reporting data permitting comparison of plant overload with average daily output. Of the reporting entries, overload capacity exceeded the average daily output by over 200 per cent in 56.4 per cent of the plants, fell between 150–200 per cent in 32.6 per cent and was less than 150 per cent in 10.7 per cent of the plants. Picton (*6*), evaluating 1953 data, reported 58 per cent of the water supply systems as having facilities considered adequate, 21 per cent uncertain, and 21 per cent inadequate.

The average rated plant capacity of the 528 plants reporting this item was 165 per cent of the average daily output

TABLE 8

Evaluation of Yields, Capacities, Distribution, and Improvements Required

Items	Utilities	
	No.	%
Safe yield	433	100.0
Over 300% of avg. daily output	203	46.9
200–300% of avg. daily output	84	19.4
150–200% of avg. daily output	63	14.5
100–150% of avg. daily output	64	14.8
Less than avg. daily output	19	4.4
Plant overload capacities	404	100.0
Over 200% of avg. daily output	230	56.9
150–200% of avg. daily output	131	32.4
Less than 150% of avg. daily output	43	10.7
Distribution systems	580	100.0
Adequate	357	61.6
Inadequate	90	15.5
Unreported	133	22.9
Improvement requirements reported	378*	100.0*
Source, underground	78	20.6
Source, surface	78	20.6
Transmission	158	41.8
Pumping	143	37.8
Treatment	153	40.5
Ground storage	109	28.8
Elevated storage	164	43.4
Distribution system	217	57.4
Other	4	1.1
None	16	4.2
Unreported	202	

* Not additive, since some utilities have more than one requirement.

which is only 3 per cent more than the maximum day demand. The average overload capacity exceeded the rated plant capacity by 25 per cent.

Distribution system adequacy for maximum demand was a reportable item on the inventory sheet; 61.6 per cent of the entries reported that the distribution system was adequate, 15.5 per cent inadequate, and 22.9 per cent failed to report on this item.

It is apparent that considerable effort should be directed toward bringing municipal water facilities up to maximum dependability for future demands. This requirement has been recognized by water works people. For example, 41.2 per cent of the entries stating their needs reported that improvements in source of supply were needed, 40.5 per cent indicated treatment needs, and 57.4 per cent showed needs for the distribution system. Other needs reported were transmission 41.8 per cent; pumping 37.8 per cent; storage 72.2 per cent; miscellaneous 1.1 per cent; no needs 4.2 per cent. Of the 580 entries, 202 or 34.8 per cent failed to report on their needs.

Future Water Demand

The water supply industry must build to meet future demands. It must serve a growing population, increasing uses, expanding industrialization and a constantly enlarging suburbia. Counteracting these factors which tend to increase demand are: [1] control by meters, [2] surveys to eliminate wastage and inadvertent losses, [3] conservation and reuse by industry to reduce costs and waste disposal requirements, and [4] general rising water costs which may prove to be the most effective deterrent to excessive use.

It is believed that these related but generally opposing forces may result in a slightly rising average per capita demand. The per capita demand will rise more rapidly in the smaller communities to approach that of the larger cities. By the year 1975, the average demand in the United States may possibly range between 155 and 160 gpcd.

Industry will continue to demand more water to satisfy its increasing production capacities. Rising costs, stricter control of pollution, and competitive pressures, however, will tend to exert control over industrial uses so that consumption per production unit will probably decrease.

A most important consideration is the growing population. Even though the average municipal per capita consumption from 1948 to 1954 showed only minor variation, the estimated population served by municipal systems of communities having populations greater than 10,000 increased 60 per cent with a corresponding increase in total consumption (*12*). It is not unreasonable to expect that semirural and even the more populous rural areas will eventually be served by public systems. The United States census (*11*) estimates that the national population in 1975 may range up to 221,000,000, a 33 per cent increase over the 1955 population. In addition, the trend toward growth of urban and suburban areas will probably continue.

Water use will fluctuate as influenced by climatic conditions; there will be peaks and valleys. Over the next several decades, however, there will be a generally constant and growing demand on the water supply industry.

Acknowledgment

It is not possible to recognize and acknowledge adequately the help and cooperation of all those participating and making possible the basic data inventory. Representatives of communi-

ties and local water facilities, state health department personnel, and members of the USPHS have cooperated in this activity. Sincere appreciation is expressed to all.

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Correction

Since the publication of "A Survey of Operating Data for Water Works in 1955" (May 1957 Journal, pp. 553–696), the following errors in the tabulation have come to light:

City	Table	Page	City No.	Column No.	Reads	Should Read
Antioch, Calif.	4 (I)	642	20	1	29	20
Corpus Christi, Tex.	4 (I)	650	106	3	1,198.7	—
				4	—	1,198.7
Springfield, Mo.	4 (II)	684	436	25	2,219	12,219
				26	25	139
Wichita, Kan.	3	641	486	13	1.33	133

Evaluation of the Use of Polyphosphates in the Water Industry

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THE statements in this attempt to separate fact from fancy in the sale and use of polyphosphates in water treatment derive from findings which have been described in reliable scientific literature. Several comments are contrary to the implications of sales representatives who lack either adequate training or the capacity to resist the temptation to oversell. Such deficiencies have resulted in misapplications which have not benefited the reputation of polphosphates in water treatment.

In a broad general sense, all polyphosphates show the same characteristics—with some notable exceptions which are of minor consequence in this discussion. These polyphosphates include the crystalline pyrophosphate, metaphosphate, and tripolyphosphate, as well as a number of glassy polyphosphate blends. Polyphosphates behave chemically in a manner quite different from the well known orthophosphates. In many ways the polyphosphates are remarkable as a class of chemical compounds.

Many claims have been made; some are adequately supported by data, but others are often misinterpretations or inferences which cannot be substantiated by suitable records. In each case the circumstances of the application must be considered. Inferences from favorable data acquired in one application are not necessarily applicable to another. The first need in any application is a statement of the end to be accomplished.

Softening of Household Water

Data are available to show that about 5–10 ppm polyphosphate are required to counteract 1 ppm hardness. Thus, for example, water with a hardness 300 ppm will require an application of 1,500–3,000 ppm of polyphosphate to soften it, or 6–12 tons per million gallons. On the other hand, considering smaller quantities, 1 oz of polyphosphate would be required to soften 10 gal of water of 300 ppm hardness. Thus, a household job such as dishwashing represents a practical application. Such softening is accomplished by a process called sequestration, or by the formation of soluble calcium polyphosphate and magnesium polyphosphate complexes.

This should not be confused with what is normally considered as threshold treatment—a stabilizing or inhibiting treatment which is designed for another purpose when treating municipal or industrial water supplies. Threshold treatment refers to the application of polyphosphate in a concentration of about 2–4 ppm. This concentration theoretically reduces the

hardness of the water by about 0.5 ppm—for example, from 300 ppm to 299.5 ppm.

Polyphosphates are normally an integral ingredient in dishwashing compounds for restaurants and household use, as well as in many synthetic detergents. A typical dishwashing machine compound contains about 40 per cent polyphosphate, 40 per cent sodium silicate, and 20 per cent soda ash.

Thus, the use of polyphosphate for softening water for domestic purposes is practicable, but exceeds the bounds of ridiculousness when it is implied that the same applies to municipal softening of hard-water supplies.

Cleaning of Wells

As cleaning and wetting agents, polyphosphates have achieved frequent notable success when used for cleaning screened sand and gravel wells. When confronted with a well problem, it is important to be sure, first, that the problem results neither from pump inefficiency, lack of water in the aquifer, nor failures in the column pipe. Where it has been determined that lack of water is due to clogged screen or a clogged water-bearing formation in the immediate area of the screen, treatment with about 30 lb of polyphosphate per 100 gal of water in the well bore has been found successful. Such treatment is often accompanied by the use of 1–2 lb of chlorine or chlorinated lime and, on a few occasions, has been in conjunction with a wetting agent of the non-ionic type. The practice of surging the well periodically during the several hours following the application of the treatment is recognized as highly beneficial. For continued success, it is desirable to repeat the application at scheduled intervals dictated by experience so that incrustation does not reach the point where this nondestructive type of treatment can no longer be applied with success.

Red Water

Rusty water may occur as the result of the natural presence of iron in the water pumped from ground water wells or it may result from iron dissolved in the water as a product of corrosion.

Iron in well water is normally present in the soluble (ferrous) state. The water is clear until, upon exposure to air or to chlorination, it is converted to the insoluble (ferric) state which reacts with water to form ferric hydroxide, or rust.

Polyphosphates have the property of being able to combine with or sequester soluble iron. They do not combine with or sequester insoluble ferric hydroxide. In view of this property, the more effective use of polyphosphate requires the application of this treatment to the water before it is exposed to air or before chlorination. Subsequent oxidation by air or chlorine will convert the iron to the ferric form, but it remains dispersed until the polyphosphate has lost its dispersing property by reversion to orthophosphate.

The amount of polyphosphate required for this purpose is about 2–4 ppm per 1 ppm of iron in concentrations up to about 2–4 ppm. At higher concentrations of iron, more than 9 ppm polyphosphate is not always beneficial.

As it has been recognized that polyphosphate is an excellent source of phosphorous for the growth of bacteria, it is normally recommended that the concentrated solution of polyphosphate for injection into the water be treated with about 50 ppm chlorine each time the solution is prepared. This prevents the development of a breeding ground

for possible coliform organisms in the polyphosphate treatment solution.

In certain areas where sufficient concentrations of ammonia, methane, or both may be present in the well water, some iron removal water treatment plants are rendered ineffective by bacterial growths in the filter bed. Such growths deplete the oxygen which was dissolved in the water by aeration for the purpose of oxidizing the soluble iron to the insoluble ferric hydroxide prior to filtration. In fact, even though chlorination is subsequently applied to the water effluent, the water mains themselves may be so infected with such growths that chlorine is destroyed by the growths faster than the reverse can occur. Subsequently, such insoluble iron as may be deposited in the mains is redissolved as ferrous iron because of the anaerobic conditions created by the bacterial growths.

Chlorination before filtration has proved to be successful in many cases. In persistent situations it may be desirable to use copper sulfate in conjunction with polyphosphate for the purpose of inhibiting the growth of bacteria while the polyphosphate keeps in soluble form such soluble iron as may be picked up from the mains. The economics of such treatment is not prohibitive for small water plants. Normally, a treatment with 1 ppm copper (2.5 ppm anhydrous copper sulfate) is adequate when applied with more than 2–4 ppm and less than 9 ppm polyphosphate.

Scale Prevention

Scale is defined here as a deposit from hard water and does not refer to either rust deposits or corrosion products. Threshold dosage of polyphosphate in water has the unique power of preventing crystal growth of calcium carbonate. Although either calcium or magnesium may be responsible for the scale, polyphosphate is effective against calcium carbonate deposits *only*; it has no effect on redissolving or preventing the magnesium hydroxide deposits so frequently encountered where lime softening plants are not operating properly.

The first of four points where calcium carbonate deposits can be controlled is the sand filter. Lime softening plants without sufficient recarbonation to prevent calcium carbonate deposition on sand frequently acquire an accumulation of calcium carbonate on the sand grains. Continuous treatment with polyphosphate in threshold concentrations (2 ppm) has frequently been reported to prevent such depositions. Magnesium hydroxide deposits which may occur at this point are no problem because they do not accumulate on the sand grain and are easily removed during backwashing.

Distribution systems constitute a second point of scale accumulation because lime softening plants with insufficient recarbonation may also deposit a rather heavy calcium carbonate scale in the main as the water leaves the plant. Again, threshold treatment with polyphosphate will prevent this accumulation at this point. However, such plants frequently also produce a water at or near saturation with magnesium hydroxide. Such lime-softening effluents are usually high in magnesium and pH and low in calcium and alkalinity or both. Deposits of magnesium hydroxide in the water main *cannot* be removed or prevented by the use of polyphosphates. There is no record in the literature to indicate the successful use of polyphosphate for this purpose.

Magnesium hydroxide or magnesium silicate, singly or mixed with calcium carbonate or residual alum form a wavy, rippled deposit that has a very serious effect upon carrying capacity. Records are available where the Hazen-Williams *C* value has been reduced from 120 to 90 or 80 with as little as a $\frac{1}{16}$-in. deposit of this rippled nature. Because polyphosphates will not prevent such a deposit and no chemical is known for postcorrective treatment, the cure is one of prevention and not of treatment.

A third point of scale accumulation is in apartments, hotels, hospitals, and similar places, where three kinds of hardness can be considered:

1. Completely softened water which will not deposit calcium or magnesium scales
2. Unsoftened hard water which usually does not scale in cold water lines (At drinking fountains or faucets, however, scale deposits may build up. Polyphosphates should correct this deposition of calcium carbonate for such hard waters. Scales in hot-water appliances and hot-water lines are usually calcium carbonate. Treatment of this condition with polyphosphate in threshold concentration should also be of benefit if the retention time at the heating point is not sufficient to revert the polyphosphate to orthophosphate.)
3. Lime-softened water, which rarely produces heavy scales in cold water lines (In fact, some calcium carbonate scale is desired for corrosion prevention. Scales in hot-water lines are common, and if the scale is calcium carbonate, polyphosphate can be of benefit, particularly if applied in recirculated systems. If, however, the scale is magnesium hydroxide, which is highly insoluble in hot water, polyphosphate treatment is worthless).

Another property of polyphosphate that should be considered lies in its behavior when exposed to high temperature and to high pH. High temperature and, to a lesser extent, high pH in hot-water tanks and at the heating point, cause a significant reversion of polyphosphate to orthophosphate within a few hours. A number of overdosage instances are on record where the orthophosphate has reacted with calcium to form a calcium phosphate or calcium hydroxyphosphate scale which actually did more harm than good. The rates for reversion for various polyphosphates vary, but there is no record of any polyphosphate that possesses desirable useful properties which is not subject to partial or complete reversion to orthophosphate within a matter of hours under high-temperature conditions.

Magnesium hydroxide scale with or without adsorbed silica in hot-water tanks can easily be removed by flushing with a hose. When such flushing of this highly heat-insulating deposit becomes necessary on a weekly or monthly basis, the water user is justified in complaining.

Scale is also frequently encountered in cooling towers where polyphosphate is frequently a part of the chemical treatment. Continuous treatment by application of polyphosphate alone is usually not completely effective. Such water use and accompanying treatment is complicated by the rate of blowdown, the pH of the water, the general water quality, the reversion rate of the polyphosphate, and the temperature of operation. The problem is frequently one of treatment to prevent corrosion, scale, and slime. Polyphosphate treatment is usually an adjunct to other treatment or is supplemented by pH adjustment, by the addition of chromates, or

zinc salts (or both), by ferrocyanide or organics for corrosion control, and even by chlorine or chlorinated phenols for slime control.

Corrosion

Corrosion is defined as the loss of metal and may be evidenced by failure of a structure, conduit, or container. In the case of ferrous metals, it may be detected by the appearance of iron in the water from the solution of ferrous metal. It may also be detected by the appearance of rust deposits on the water side of the metal. These deposits may be uniform, as in general corrosion, or knobby growths, as in pitting and tuberculation.

The appearance of iron (red water) as a result of corrosion may not be in significant quantities at high velocities because of dilution, but can be considerable at low velocities because of the longer contact time. On the other hand, the corrosion rate necessary to induce structure failure may be greater at high velocities but insignificant at low velocities.

The presence of iron in the water is not necessarily an indication of corrosion, because it may have been present in the water before contact with the metal vessel. The appearance of a rusty scale is not always evidence of corrosion because it may be a deposition of hardness together with iron which was originally present in the water.

Polyphosphates have been reported to be effective in reducing corrosion by domestic waters. The reliable data show this effectiveness only under certain conditions and with certain types of waters. Corrosion prevention cannot be claimed, even though the red water effects of natural iron in the water have been lessened by the use of polyphosphates, nor can prevention be claimed where red water is avoided by sequestration of this iron corrosion product. Improvement but not prevention can be claimed in situations where pitting-type corrosion is altered to generalized corrosion.

The effectiveness of polyphosphates is progressively greater at increasing turbulent velocities and at increasing concentrations. Under essentially no conditions are polyphosphates effective in stagnant or nearly stagnant water, such as in dead ends or service lines. The only data available on its effectiveness at low velocities appear to indicate a slight increase in corrosion at 0.5 fps. It should be recognized that conditions of 2–5 fps or more of turbulent flow velocities are not experienced continually in all parts of almost any distribution system, and certainly not in communities where the grid has been designed with 5–10 miles of 4- and 6-in. pipe for a 30,000 gpd consumption. Considerable embarrassment could be avoided if vendors as well as superintendents would calculate the velocity of flow in 4-in. dead ends at normal domestic consumption rates by a limited number of families.

In hot-water systems, the corrosion rates are usually greater than in cold. Recirculation improves the effectiveness of polyphosphates or of any inhibitor in hot-water *systems*, but, because of the low velocity, not in hot water *tanks*. It can, however, improve the ability of the treatment to maintain such iron as is dissolved by corrosion in solution.

There is room for definition of water quality as related to its corrosive properties. All waters are not equally corrosive and it should be recognized that the quantity of polyphosphate required may vary depending on the water

quality as well as the specific conditions of use. Any large-scale application and most small-scale applications for corrosion control, warrant well planned and complete corrosion testing to establish data on effectiveness at the specific applications and velocities involved.

Cleaning of Water Mains

Reported experiences vary with regard to the effectiveness and even the desirability of using polyphosphates for water main cleaning. The usual procedure consists of mechanical removal of bacterial slime, debris, mineral deposits, or corrosion products. On occasions, little discussed in scientific journals, polyphosphates or other chemicals have been used as an adjunct to mechanical cleaning. No clear, reliable assessment of the value of this function is available, nor is it reasonable to expect a valid evaluation without more exact data than have been published to date.

The use of polyphosphates as an adjunct to mechanical cleaning must be followed by effective water treatment if the cleaning is to have a lasting effect. If the subsequent treatment is done with polyphosphates for corrosion control, the limitations inherent in low-velocity mains must be recognized.

Nonmechanical removal of corrosion products and deposits other than calcium carbonate has been proposed and attempted, often with embarrassing results. It would appear that the primary problem is that of defining the deposit to be removed and the quantity. These unknowns are further complicated by a butcher's guess on the quantity and method of application of polyphosphate. When it is recognized that even the manner of action of polyphosphate on the various unknown deposits or corrosion products is not clearly established, nonmechanical water main cleaning with polyphosphates must be considered as nothing more nor less than a calculated risk. There is no established and proved plan or specification for nonmechanical removal of noncalcareous deposits.

Conclusion

Polyphosphates are a truly remarkable class of chemicals. Their effectiveness for many purposes has been demonstrated in the laboratory and by practice. Their ineffectiveness for other purposes has also been established in the laboratory as well as by experience. It is unfortunate that no specific data are available for the cure-all misapplications which have resulted in disastrous failures and chaotic difficulties.

Revenue-producing Versus Unaccounted-for Water

Committee Report

A report of Committee 4450 D—Revenue-producing Water, presented on May 13, 1957, at the Annual Conference, Atlantic City, N.J., by E. Shaw Cole (Chairman), Pres., Pitometer Assoc., New York, N.Y. Other members of the committee were: Ellwood H. Aldrich, E. Jerry Allen, David Auld, Egbert D. Case, Oswald A. Gierlich, Dewey W. Johnson, Arthur P. Kuranz, Howard W. Niemeyer, W. K. Van Zandt, and Howard R. Wright.

THE increase in the demand for water due to improved living standards, population growth, and industrial expansion is rapidly approaching the limit of the great natural resources. Most communities are finding it increasingly difficult and expensive to enlarge their sources of supply and plant facilities, so that the incentive to conserve their existing supply is greater than ever.

The cost of an additional supply is frequently more expensive than the original construction because of the need to go a greater distance from the community or to develop a new source which has less yield per invested dollar or simply because of inflation. Ground water is being depleted, and water tables are being lowered. The least expensive supplies were developed initially; but even without considering the steady rise in construction costs, future supplies will be almost certain to cost more than the existing ones.

Conservation is, therefore, a fundamental part of water works operation in an established community, due to the direct money savings in operation and the longer range savings from deferred capital costs for plant expansion.

Direct savings can be made in the cost of production by reducing the amount of chemicals or power consumed, or, if the water supply is purchased, the saving is in dollars paid to the wholesaler. Deferment of the need for plant expansion saves capital expenditures, and is thus another type of saving.

Transmission mains and distribution systems need to be expanded or reinforced when their designed capacity is exceeded, so as to maintain adequate pressures and a satisfactory reserve capacity. Reservoirs, standpipes, and elevated tanks likewise may need to be expanded as consumption increases.

This report is intended to aid the water works industry in its efforts to evaluate and improve conservation practices. It furnishes the operator of the water works plant complete information on the items which must be considered in accounting for the water supplied to the distribution system. If a proper analysis is made, he then will be in a position to determine whether his plant is being operated at maximum efficiency; or if not, what steps he should take to improve conditions.

An audit of the water delivered to the system will provide a basis for comparison with other systems, and a method for evaluating the conservation procedures. The data used in the audit must be accurate and include metered delivery to the distribution system, metered sales, and metered ratio—that is, the ratio of metered sales to metered delivery.

Delivery and Sales

Total metered delivery to the distribution system preferably should be determined by a master meter installed on the mains supplying the system with treated water. This should not include use or waste at the filter plant, pump station, or supply works.

Total metered sales should be determined for the shortest period that is economically feasible, usually from 1 to 6 months, depending on the size of the system, dial capacity of meters, and billing procedures. The three principal types of sales are: [1] industrial and commercial, including water for irrigation; [2] domestic or residential; and [3] public use.

Industrial and commercial meters should be read monthly, whereas meters recording domestic or residential consumption should be read as often as feasible, and if not monthly, the readings should be adjusted to allow for seasonal variations in consumption, so that reasonably accurate comparisons can be made.

All public use should be metered, and readings made periodically whether or not a charge is made for the water used. This includes such items as use in schools and other publicly owned buildings, hospitals, and charitable institutions. Also included is use by public works agencies such as water, sewer, and street departments for construction and operating programs, as well as fire department use and waste and park department use and waste.

If actual metered use is not feasible, as in fire fighting, the amount used should be estimated, based on the number and size of hose streams, pressure, and length of time used. Accurate records should be kept of all such use. Street department watering trucks, if not metered, should record the capacity of each tank and the number of tank loads used each day. If it is not possible to secure this information, no amount should be included in the metered sales. The omission can be indicaetd by a footnote when making reports, and for comparative purposes the amount of such unmetered use should not be estimated in excess of 1 per cent.

Metered Ratio

Determination of the metered ratio is the first step in evaluating performance. Good performance is generally indicated by a metered ratio of 85–90 per cent, where the use of water is between 100 and 125 gpcd. Where large industrial use causes a higher per capita use, the ratio may approach 100 per cent. The difference between the metered ratio and 100 per cent is unaccounted-for water. This may vary from 10 to 15 per cent in a well operated system where the consumption is between 100 and 125 gpcd.

The metered ratio will vary, depending on the type of system and other factors. The effect of these is usually obvious, and although much has been written about each one, they are described briefly below:

Age of system and ground conditions. In determining whether or not the metered ratio is satisfactory, the age of the system and ground conditions must

be considered. In an old system a large amount of unavoidable leakage must be expected, that is, the leakage which it would cost more to locate and repair than to permit to exist. The ground conditions should not influence the conclusion as to whether or not the plant is operating efficiently, but if they are such as to permit water to escape easily, involving presence of rock, gravel, or sand, the possibility of hidden underground losses is much greater, and if the unaccounted-for loss is too high, steps should immediately be taken to locate these losses.

Unavoidable leakage. This item can be described in general as the amount of underground losses in mains and services of the distribution system that would cost more to locate and repair than to permit to exist. The amount will vary from the allowable leakage cited in Section 13.7 of the Standard for Installation of Cast-Iron Water Mains (AWWA C600) in the test of a newly laid cast-iron pipeline—"70 US gal per 24 hours per mile of pipe per inch of nominal diameter for pipe in 12 ft lengths evaluated on a pressure basis of 150 psi." (*1*)—to 3,000 gpd per mile of main, a figure that has been determined by various formulas to be a reasonable value in an average eastern city distribution system. Experience has shown that the value may range from 1,000 to 3,000 gpd per mile of pipe, depending on the age of the system, ground conditions, type of pipe and services, type of community, pressures, and source of supply.

Pressures and source of supply. Pressures have a definite effect on the metered ratio, since the higher the pressures the greater the amount of avoidable and unavoidable waste. For example, outlets will discharge approximately 40 per cent more water under a pressure of 100 psi than under that of 50 psi. High pressures also have a tendency to create more leaks by forcing calking in pipe joints and causing more rapid wear in the moving parts of water facilities. Therefore, a larger unaccounted-for figure is permissible where high pressures exist than under low pressure conditions.

Whether the supply is by gravity or pumps effects the necessity of reducing the unaccounted-for figure to a minimum. Obviously, if the supply is by gravity and plentiful, there is little or no production cost, except water treatment, and if the supply is ample, the incentive to take expensive means to maintain a high metered ratio is not great. If the supply is limited, however, everything possible should be done to conserve the available supply and put off the expense of building new reservoirs and laying pipelines for as long as possible. When the supply is pumped there is every incentive to reduce the unaccounted-for water to a minimum, as water then becomes a costly product and the daily operating cost can be reduced by the elimination of waste. Also, the need for plant expansion can be postponed.

Quality of materials and workmanship. These items can have a decided effect on the metered ratio, usually depending on whether or not the mains are laid by contract or by the employees of the water department or company, and also the quality of the specifications used and the inspection provided.

The proper type and weight of pipe should be used to meet local conditions, and valves, hydrants, and other special items should be of the best possible design and manufacture.

Use per capita and per mile of main. The per capita consumption is not con-

clusive evidence of the waste conditions in a system, and does not necessarily determine whether the metered ratio is satisfactory. In order to have any significance, the metered consumption should be divided among domestic, commercial, and industrial use. In developing a per capita figure, industrial used should be omitted, and if the remaining figure is higher than the average for comparable systems, the unaccounted-for water should be investigated even though the metered ratio seems to be reasonably high. The accuracy of per capita figures is dependent on census figures that are usually obtained once every 10 years, and figures for the intervening years may be greatly in error. The average use per customer can be computed more accurately at any time, and this method is recommended for use in the future for comparative purposes.

The use per mile of main is also an inconclusive figure, and should be analyzed carefully before being applied to the situation at hand. In industrial and thickly populated apartment house areas, the consumption per mile of main can be legitimately high, while in purely residential sections, the use per mile of main should be correspondingly low. In a residential community the allowable unavoidable leakage will constitute a substantial percentage of the unaccounted-for water, and, consequently, a comparatively low metered ratio is allowable. The converse is true in a system predominantly industrial and commercial.

Amount of industrial and commercial use. The amount of industrial and commercial use is probably the most important factor in determining whether or not the metered ratio is satisfactory. The type of city may vary from a purely residential community to a heavily industrialized city where the use through meters of 2-in. and larger diameter may amount to as much as 75 per cent of the total consumption. In the former case, a metered ratio of 80 per cent may be satisfactory because of the low consumption per mile of main, and in the latter case even with a metered ratio of 90 per cent there may be much avoidable waste. The only dependable method of securing a metered ratio from which definite conclusions can be drawn is to eliminate the industrial use from all consideration.

Amount of underregistration and the unauthorized use. The actual underregistration of domestic meters in a system can vary from 2 per cent to as high as 15 per cent, depending on the local meter maintenance program. The majority of state public service commissions require private water companies and, in some states, municipal water departments, to remove domestic meters for replacement or repair at least once every 10 years. The optimum frequency of meter repairs is dependent on local conditions that may vary widely throughout the country, but an overall allowance for underregistration of 3 per cent should be economically feasible. Industrial meters should be tested in place under operating conditions, if possible, at least once a year, and with exceptionally large consumers a monthly test is desirable.

The unauthorized use of water sometimes proves to be an important factor in the case of a low-metered ratio. The most likely cause of unauthorized use is through an unmetered fire line, or, in rare cases, the deliberate bypassing of an industrial meter. One

method of controlling unauthorized use through fire lines is by the installation of detector-type meters, but this is not advisable if the service is used for both industrial purposes and fire protection. The best practice is to separate the fire line from the industrial service with the proper type of meter on the industrial service and a detector device on the first line.

Per Capita Loss

A second index of performance is the difference between the metered delivery and metered sales expressed in gallons per capita served per day, otherwise known as the per capita loss. Where the total delivery to the system is less than 80 gpcd, the per capita loss may have more significance. A loss of 10–12 gpcd may be satisfactory even though the metered ratio is lower than 85 per cent. In a similar way, the significance of losses per customer should also be studied and evaluated. If, after making allowances for the applicable variables in a table of accounted-for water, the ratio is not satisfactory, underground leakage or underregistration of meters is indicated.

Importance of Maintenance

Good maintenance will, in general, result in a high metered ratio and low unaccounted-for figure. A low ratio should not be accepted as indicative of good performance without proof that it cannot be improved. The major points to be included in a good maintenance program are:

1. *Definite program of meter testing and repair.* Accuracy of the master meters as well as industrial and domestic meters is essential. Domestic meters should be removed for testing and repair periodically, the period between testing to be determined by experience in each system, and all commercial and industrial meters 2 in. and larger in diameter should be tested at least annually, in the field if possible.

2. *Definite program of leakage and waste control by comprehensive surveys.* The frequency of these investigations should be determined by changes in the metered ratio and the results obtained by the program.

3. *Complete records of operating procedures of all types.* The indexes of metered ratio and per capita loss will immediately reflect conditions needing correction.

4. *Periodic operation of valves and hydrants and proper maintenance if necessary.*

Unmetered Systems

For unmetered systems the methods of evaluating conservation practices cannot be so accurate. As in the case of the metered system, the amount of water supplied to the distribution system should be measured by master meters. Also the amount of water used by industrial and commercial accounts should be metered. In many unmetered systems some domestic accounts are metered either at the request of the consumer or in accordance with a policy of selective metering, whereby wasteful accounts are metered.

A table of accounted-for water can be prepared on the basis of the metered accounts and allowances for underregistration of meters, and for public uses as previously described. The domestic unmetered use can be estimated by using a figure of 60 gpcd, of which 50 gal is for actual use and 10 gal for uncontrolled leakage in the plumbing fixtures. A figure of 3,000 gpd per mile of main can be used for unavoidable

leakage. The amount of unaccounted-for water can then be determined by use of these factors, and will be valuable for purposes of comparing the efficiency of local operations from time to time. Other valuable standards are per capita consumption, consumption per customer, consumption per mile of main, and minimum night rate of consumption.

The amount of each of these may vary widely, and local conditions should be carefully considered when interpreting them or making comparisons with other systems.

Conclusion

Since this report is intended to present methods for evaluating conservation procedures and methods of improving performance, no attempt has been made to recommend specific techniques. Different techniques may be equally effective in obtaining a high metered ratio, and the results obtained are of primary interest to this committee.

Many articles on this subject have been published in the JOURNAL, and lists of these can be found in the indexes (2–3). Recent articles are indexed yearly in the December issue. Other publications with articles of interest include *Public Works*, *Engineering News-Record*, *Water Works Engineering*, *The American City*, *Water and Sewage Works*, and *Journal of the New England Water Works Association*.

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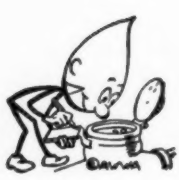

Factors Limiting Financing of New Water Works Construction

Alfred LeFeber

A paper presented on Sep. 19, 1957, at the Ohio Section Meeting, Cincinnati, Ohio, by Alfred LeFeber, Cons. Engr., Cincinnati, Ohio.

FORTY years of experience have provided much information concerning construction costs, most of which were directly related to market conditions—for it is impossible to escape the consequences of the market and the implications of these consequences. Before the present period, the advance and decline of money costs, closely paralleling the so-called business cycle, has been a common phenomenon. At no time in that period was there a constant upward trend without much apparent reason, as there is at present. The upward trend referred to is that shown by the unit costs and the labor and material costs of water works construction. This trend is definitely tied to the inflationary spiral which most recognize but few understand.

For nearly 20 years the apparent cost of money was low and money was regarded as cheap. However, the cheap money cost was and is reflected in higher commodity costs so that any endeavor in the water works field is, like everything else, caught in the upward inflationary trend. This is not an attempt to explain inflation or to suggest a cure—if one is desirable—but is simply intended to direct attention to the factors which increase water costs today.

Housing Practice Factor

One of the contributing factors apparently completely overlooked is a trend manifested in present subdivision and housing development practices. Because of limited transportation and other considerations 40 or 50 years ago, the average residential property was a lot 50×120 ft. Many of the old installations were financed by general obligation bonds at interest rates ranging from 3 to 5 per cent. No attempt was made to employ other means of financing, largely because there was no market for other securities and because the quality of these other types of securities had not been established. With present constitutional tax limitations, ways have been sought to finance various types of public improvements by means other than general taxation, in order that improvements of general benefit in an intangible sense could be financed by general taxation. The search resulted in the development of the revenue bond which is based upon rates adequate to service self-liquidating public facilities.

Increase in Materials

As the newer trends in subdividing and home building have progressed, the water works industry has found that the quantities of material necessary to

serve a single residence have increased 50–100 per cent. This increase is expressed in dollars and in terms of physical items necessary to accomplish a construction goal. Thus, if, years ago, 50 ft of pipe were required to service a residential lot, 75–100 ft are now required to service a single residential unit. Where, years ago, the financing was guaranteed by general taxes, the security buyer felt that no additional protection was necessary. Today, because of early abuse in the field of revenue financing, security buyers insist upon reserve or coverage to the extent of 50 per cent above average or, in some cases, maximum annual debt service. This, of course, is immediately reflected in rates to be charged for the commodity—when cost is not broken up into a number of categories such as general taxation, special assessments, and water service. Today, the average water bill in communities where water facilities are financed by revenue bonds reflects not only the cost of the commodity but the debt service and reserve or coverage as well.

Investor Reluctance

The difficulty in marketing securities involving high rates arises from the fact that many water systems, based upon smaller lots and general taxation, reflected rates sufficient to defray operating costs only. A few short years ago, $1 per month was considered an ample charge for water service at the minimum level. Security buyers are hesitant to purchase securities where the monthly cost for minimum service will be as high as $7–$9 and where it will sometimes reflect 40-year debt retirement. It has been an extremely difficult task to educate the security consumer in order to encourage purchase of securities. Of considerable importance in this respect is the differentiation between real-estate developments and bona fide customers.

As a result of prior unhappy experiences, the security buyer will not invest in speculative real-estate developments. This means that in order to finance entirely new construction, guarantees must be arranged to satisfy the security buyer that there will be an adequate number of customers at a given rate to satisfy the investment and all of the indenture requirements. In recent years engineers have been compelled to perfect contractual and other arrangements by which progress can be made. In many instances, a chicken-or-the-egg situation exists, where federal underwriting of houses and, consequently, water consumers is held up pending the guarantee of public water supply and sanitary-sewer facilities. These facilities cannot be financed without the houses. The houses will not be financed without the facilities, and so it goes.

Conclusion

A means must be devised whereby the circle is broken and the project can go forward. This can be accomplished on almost any scale, but will require much paper work and complete disclosure of all the facts so that the developer will be aware of his part, the potential homeowner will know what his minimum monthly water expense will be, and the security buyer can be informed of all factors necessary to elicit his investment.

1957 Conference—Atlantic City

THE first 3,000 registration was the headline news of AWWA's 77th Annual Conference, held last May 12–17 at Atlantic City, N.J., but even more memorable to the 3,067 who were on hand was the biggest and best program of technical sessions, exhibits, social functions, and other features ever scheduled. The rapid growth of the Association's meetings, both in attendance—which has risen 50 per cent in the past 3 years—and in outlook, is a direct reflection not only of the growth of AWWA itself, but of the growth of interest in water. And through the week, there was no question that water was in its element at Convention Hall, at the eight hotels that provided housing, and throughout the resort city and its many famous restaurants.

Host-in-Chief and Arranger Extraordinary for this record crowd, as chairman of the Convention Management Committee, was J. Leslie Hart, whose task was shared with:

Representing AWWA	*Representing WSWMA*
Charles J. Alfke	Louis F. Frazza
Lewis W. Klockner Jr.	Thomas T. Quigley

Ex Officio

Paul Weir, *President*	Harry E. Schlenz, *President*
Harry E. Jordan, *Secretary*	John G. Stewart, *Manager*
E. Shaw Cole, *Chm., Publication Com.*	

Helping to make even the business of the meeting a pleasure, Shaw Cole's Publication Committee set up fifteen technical sessions that ran the gamut of present problems. Featured by discussions of saline-water conversion, reservoir evaporation control, cloud seeding, water resources development—including an address by New Jersey's Governor Meyner—fluoride application, and water utility earnings, the program drew record audiences and record enthusiasm. A complete list of the papers presented appears on pages 1602–04. Those that have already been published in the Journal may be located by reference to the annual index (pages 1619–37).

A pleasure that was really mouth-watering, too, was provided by 101 of AWWA's Associate Members, who covered 20,000 sq ft of the Atlantic City Auditorium with the kind of equipment and materials that every water utility man wanted to take home. To John Stewart and his Exhibit Committee, the 197 boothsful of exhibits represented a new peak not only in quantity, but in quality as well, providing a strong complement to the rest of the technical program.

And finally, through the efforts of Lew Klockner, Hubert O'Brien, Harvey Howe, Sid Wilson, Bill Reinicker, and Harold Ohland, the planned pleasure was more than a pleasure from the Boardwalk Buffet that started the fun on

1957 CONFERENCE STATISTICS

Atlantic City Registration by Days

Day	Men	Ladies	Total
Sunday, May 12	1,179	401	1,580
Monday, May 13	775	247	1,022
Tuesday, May 14	230	21	251
Wednesday, May 15	157	—	157
Thursday, May 16	57	—	57
TOTALS	**2,398**	**669**	**3,067**

Geographic Distribution of Registrants

UNITED STATES & TERRITORIES

Alabama	28
Arizona	9
Arkansas	5
California	103
Colorado	28
Connecticut	45
Delaware	13
Dist. Columbia	38
Florida	30
Georgia	41
Hawaii	2
Illinois	177
Indiana	80
Iowa	46
Kansas	27
Kentucky	25
Louisiana	27
Maine	7
Maryland	77
Massachusetts	83
Michigan	98
Minnesota	21
Mississippi	7
Missouri	67
Montana	3
Nebraska	15
New Hampshire	3
New Jersey	354
New Mexico	1
New York	498
North Carolina	39
North Dakota	4
Ohio	171
Oklahoma	5
Oregon	8
Pennsylvania	495
Puerto Rico	6
Rhode Island	28
South Carolina	18
Tennessee	37
Texas	58
Utah	5
Virginia	55
Washington	15
West Virginia	21
Wisconsin	37

CANADA

Manitoba	1
Ontario	77
Quebec	9

FOREIGN

Asia	7
Europe	4
Latin America	9
TOTAL	**3,067**

Comparative Registration Totals—1948–1957

Year	Place	Men	Ladies	Total
1957	Atlantic City	2,398	669	3,067
1956	St. Louis	2,026	510	2,536
1955	Chicago	2,075	512	2,587
1954	Seattle	1,536	527	2,063
1953	Grand Rapids	1,532	365	1,897
1952	Kansas City	1,600	386	1,986
1951	Miami	1,415	491	1,906
1950	Philadelphia	1,678	329	2,007
1949	Chicago	1,593	374	1,967
1948	Atlantic City	1,348	356	1,704

Win, Place & Show in Section Awards

Henshaw Cup

Cuban	**84.6%**
Rocky Mountain	82.9%
Montana	64.8%

Hill Cup

Indiana	**48.37**
Iowa	24.44
Nebraska	23.55

Old Oaken Bucket

California	**1,349**
Southwest	1,058
New York	834

Sunday night right through the last dance of the Thursday ball. On Monday night, the Rutgers Glee Club helped the officers and awardees do the honors at a reception and dance. On Tuesday, Ray Middleton and a troupe of Broadway music makers enthralled everyone with a program of Victor Herbert, Stephen Foster, and Sigmund Romberg. A golf tournament on Tuesday and Wednesday evening free to discover the delights of Atlantic City helped build up the week's enjoyment to its climax in the Annual Dinner & Dance that this year paid tribute to William Whitlock Brush for his 35 years as an AWWA officer. That the 1,200 on hand to honor Bill Brush and to welcome Fred Merryfield into presidency included eighteen of AWWA's past-presidents helped make the affair still more memorable.

To get everyone there and back home again, Lou Frazza and his Transportation Committee catered to a record in travel needs, and catering to a record in other requirements was the whole New Jersey Section as well as many of its Pennsylvania Section friends. Meanwhile, the ladies were taking care of themselves in record numbers too—in numbers present as well as number of things to do. It was Louise (Mrs. Karl) Mann and her distaff staff, headed by Missuses F. G. Merckel, C. G. Bourgin, P. S. Wilson, and J. A. Frank, who made the whole week a party for water wives.

Association Awards

Honorary Membership was conferred upon Albert E. Berry, Charles H. Capen, S. Logan Kerr, and Willibald A. Kunigk. The citations follow:

Albert Edward Berry, General Manager & Chief Engineer, Ontario Water Resources Commission: *member of the Association since 1920; Life Member 1950; President 1952; Director for the Canadian Section 1937–40; Fuller Award 1938; Goodell Prize 1950; one who is devoted to the advancement of engineered sanitation and whose leadership has been recognized by the Canadian members whom he has served for more than twenty-five years as Secretary; a gracious gentleman.*

Charles Herbert Capen, Consulting Engineer; retired Chief Engineer of North Jersey District Water Supply Commission: *member of the Association since 1930; President 1953; Director for the New Jersey Section 1947–50; Chairman of the Publication Committee 1947–51; Fuller Award 1938; one who has served competently and conscientiously in important engineering projects of great value to the users of the service provided.*

Samuel Logan Kerr, Consulting Engineer, S. Logan Kerr & Company, Inc., Flourtown, Pa.: *member of the Association since 1935; one who is internationally recognized for his superior competence in the field of hydromechanics; ever willing to serve in widening the general understanding of difficult hydraulic problems.*

Willibald Alphons Kunigk, Retired Superintendent & Chief Engineer of the Water Division, City of Tacoma, Wash.: *member of the Association since 1924; Life Member 1954; Director for the Pacific Northwest Section 1930–32; of foreign birth, imbued with the true pioneer spirit of the Northwest, self-educated, devoted to the advancement of sound engineering and service to his neighbors, a personality highly esteemed throughout the Pacific Northwest, whose competence as an engineer has been widely recognized by professional societies.*

The John M. Diven Medal, awarded to the member whose services to the water works field during the preceding year are deemed most outstanding, was presented to John H. Murdoch Jr. The citation follows:

John Huey Murdoch Jr., Consultant (recently retired Vice-President and Counsel) American Water Works Service Company: *for his many contributions to the water works industry manifested by his provocative discussions of industry problems; his articulate presentations to the membership have stimulated thinking along constructive lines.*

The John M. Goodell Prize, granted for the best paper published in the Journal from October 1955 through September 1956, was conferred upon Thurston E. Larson. The citation follows:

Thurston E. Larson, Acting Chief, Illinois State Water Survey: *for his paper entitled "Report on Loss in Carrying Capacity of Water Mains" as published in the November 1955 issue of the Journal* (Vol. 47, page 1061). *Dr. Larson's paper deals in a scholarly way with one of the most important problems in the entire water works industry and has high value to both the technology and the literature of the field.*

Division Awards, granted for the best Journal paper (October 1955–September 1956) in the field of interest of each of the four AWWA Divisions, were presented to Jack W. MacKay, Louis R. Howson, John R. Baylis, and Warren J. Kaufman and Gerald T. Orlob. The citations follow:

Distribution Division Award: Jack Whiting MacKay, Vice-President-Sales, American Cast Iron Pipe Company, Birmingham, Ala.: *for his paper entitled "Development and Use of Specifications for Cast-Iron Pressure Pipe and Fittings." This paper, published in the July 1956 issue of the Journal* (Vol. 48, page 863), *records an understandable analysis of a series of standards of great importance to the water supply field.*

Management Division Award: Louis Richard Howson, Consulting Engineer, Alvord, Burdick & Howson, Chicago, Ill.: *for his paper entitled "Rates, Revenues, and Rising Costs." This paper, published in the May 1956 issue of the Journal* (Vol. 48, page 465), *is another demonstration of the author's capacity to think clearly and express himself convincingly upon the basic problems of our industry.*

Purification Division Award: John Robert Baylis, Engineer of Water Purification, Department of Water and Sewers, Chicago, Ill.; *for his paper entitled "Seven Years of High-Rate Filtration." This paper, published in the May 1956 issue of the Journal* (Vol. 48, page 585), *has great value in its demonstration of the propriety of revising certain long-held criteria in water treatment.*

Resources Division Award: Warren John Kaufman, Professor of Sanitary Engineering, and Gerald Thorvald Orlob, Assistant Professor of Civil Engineering, both of the University of California, Berkeley, Calif.: *for their paper entitled "Measuring Ground Water Movement With Radioactive and Chemical Tracers." This paper was published in the May 1956 issue of the Journal* (Vol. 48, page 559). *Its great value lies in its critical analysis of the merits and deficiencies of the procedures studied. A forward looking study of an important problem.*

The Harry E. Jordan Scholarship Award, granted to further the education of deserving applicants from the East (a different region is selected each year), was conferred upon Herbert H. Hassis, senior in civil engineering at Clarkson College, Potsdam, N.Y., and Wilbert H. Schlimmeyer, graduate student in sanitary engineering at Rutgers University, New Brunswick, N.J.

The George Warren Fuller Awards were presented to 25 men whose Sections had nominated them in the year beginning with the 1956 Annual Conference at St. Louis and ending with the opening of the 1957 Conference at Atlantic City. The awards—which are conferred for "distinguished service in the water supply field and in commemoration of the sound engineering skill, the brilliant diplomatic talent, and the constructive leadership of men in the Association which characterized the life of George Warren Fuller"—went to the following men:

Alabama-Mississippi Section—Jesse Lee Haley: *for his untiring efforts in the establishment and conduct of the Mississippi water works operators short course; for his deep interest in the success of the Section; and for his long years of unselfish service to his community.*

Arizona Section—Robert Milner Cushing: *for his service as secretary and chairman of the Arizona Section; for his committee work; and for his many years of faithful and effective service to his state and his profession through his constructive leadership and engineering skill.*

California Section—William Charles Welmon: *for his work as chairman of the committee which developed the "Rules and Standards for Design and Construction of Water Systems" adopted by the California Public Utilities Commission; and for his leadership in the formation of the Section's Business Management Division.*

Canadian Section—Antoine Valentine DeLaporte: *for a distinguished contribution to the public service of the province of Ontario, directed to maximum*

utilization of laboratory investigations, to far-reaching research programs, and to new developments in water purification processes and in related fields of sanitation.

Chesapeake Section—EZRA BAILEY WHITMAN: *in recognition of his distinguished service as a public official and practicing engineer; his active and continuing participation in the affairs of the Section since its organization; and his interest in the training and development of younger engineers.*

Cuban Section—LEANDRO DE GOICOECHEA: *for his complete dedication to and constant work for the benefit of the Section, as well as for his valuable work related to problems of hydraulics and sanitary engineering in Cuba.*

Florida Section—WYLIE WEEDEN GILLESPIE: *in recognition of his outstanding leadership in the water works field; his sound engineering talents; brilliant and diplomatic approach; and his services to the Florida Section, particularly as chairman and director.*

Illinois Section—HORACE RAYMOND FRYE: *for his capable direction of the expansion of his city's water system; his many years of leadership and service to the Section; and his ten years of pioneering study of the fluoridation of his city's water supply, the first installation in Illinois.*

Indiana Section—MARSHALL PAYNE CRABILL: *in recognition of his contributions to and continuing interest in sound operating procedures; his unstinting services to the Association and the Section; and his qualities of leadership and understanding which have so benefited the employees under his supervision.*

Iowa Section—THOMAS WESLEY THORPE: *for his many years of devoted service to the AWWA, to the old Missouri Valley Section, and to the Iowa Section; and for the generous sharing of his competency in the development of water supplies within his own and neighboring states.*

Kansas Section—RUSSELL LOUIS CULP: *for his study of Kansas water problems; for his contribution to improved water works practice through Association committees and the water works school; and for his engineering ability, genuine modesty, and sound leadership.*

Kentucky-Tennessee Section—JULIAN ROANE FLEMING: *for his helpful assistance to the water works operators in Tennessee; for his many valuable contributions to their training in the water works operators schools; and for his loyalty and services to the Kentucky-Tennessee Section.*

Michigan Section—ROBERT LETTS MCNAMEE: *in recognition of his outstanding contributions in water supply engineering, including filtration practice and distribution system design; and his constructive participation in committees of the Section.*

Missouri Section—ELLSWORTH LINCOLN FILBY: *for sincere devotion to the profession of sanitary engineering; for outsanding achievement in the affairs of the Association at the national level; and for helpful guidance in matters of policy and the activities of the Missouri Section.*

New England Section—ARTHUR D. WESTON: *for his inspiring leadership in the development and protection of water resources; his continuing interest in re-*

search; his broad vision and good judgment in the evolution of water policy; and his patience in counseling young engineers and water works officials.

New Jersey Section—GEORGE DUSENBURY NORCOM: *for his many years of service to the water works profession as a chemist and sanitary engineer; his services to the Section as an officer and director; and for his contributions to the science of water purification.*

New York Section—REEVES NEWSOM: *for devotion to the betterment of the entire water works field through his activities at both Section and Association levels; for the respect engendered for himself and his chosen profession in his services as the Association's president, as consulting engineer, and as village manager.*

North Carolina Section—WILLIAM WITTY ADKINS: *for his untiring efforts and activity in the water works operators school; and in recognition of his services to the Section as chairman, vice-chairman, and trustee.*

Ohio Section—CHARLES EDWIN BEATTY: *in recognition of his leadership and services to the Ohio Section, particularly as director; for his untiring efforts to promote district activities within the Section; and for his continuing loyalty and services to the water profession.*

Pacific Northwest Section—ARTHUR STANLEY GORDON MUSGRAVE: *for distinguished service in the water supply field; loyal devotion to the Section's welfare; and, in all the Association's undertakings, the unselfish gift of himself, which characterized the life of George Warren Fuller.*

Pennsylvania Section—JOHN HUEY MURDOCH JR.: *for his long and distinguished service to the Association and to the water works industry, in management, operation, and civil defense, particularly concerned with the legal aspects and the responsibility incumbent upon all engaged in endeavors so vital to the public health and welfare.*

Southeastern Section—WILLIAM THOMAS LINTON: *in recognition of his outstanding service to the water works field as state sanitary engineer for South Carolina; director of the state water pollution control authority; former secretary of the Section; and former secretary of the state water and sewage association.*

Southwest Section—J. RICHARD PIERCE: *for his active participation and leadership in the affairs of the Southwest Section; for his services as Section director; and for his professional and civic endeavors in the advancement of the water works profession in his community and his state.*

Virginia Section—WILLIAM RAY ODOR: *in recognition of his successful efforts to maintain the high standards of the social and technical programs of the Virginia Section; and for his excellent representation of Virginia water works men at the annual meetings of the Association.*

Wisconsin Section—JAMES EARL KERSLAKE: *for the work to which he devoted countless hours over a period of twenty-six years as committee member and chairman in the preparation of standard specifications for nineteen chemicals used by the water supply industry; and for his untiring efforts toward the success of the Section's meetings and activities.*

Schedule of Conference Papers and Reports

MONDAY MORNING, May 13

Water Resources Division

Land Policy for Impounding Reservoirs....Francis S. Friel
Discussion....E. S. Chase & H. J. Graeser
Public Access to Lands Surrounding Impounding Reservoirs....
Daniel P. Morse, E. Jerry Allen & John W. MacFarland

Water Works Administration Committee—Open Session

Progress Reports of Committees
Joint Administration of Water and Sewage Facilities....L. N. Thompson & R. J. McLeod
Water Main Extension Policy....L. S. Finch
Revenue-producing Water....E. Shaw Cole
Rating Scale for Water Works....John H. Murdoch Jr.
Safety Practices....R. J. Faust
In-Service Training....R. J. Faust
Publicity Program....E. L. Filby
Air Conditioning....E. L. Bean

MONDAY AFTERNOON, May 13

Water Distribution Division

Underground Arteries, 1956—Motion Picture....Johns-Manville Sales Corp.
Applications of Automation—Panel Discussion
Philadelphia Water System....V. A. Appleyard
Long Island Water Company....S. C. McLendon
Solution Effects of Water Upon Cement and Concrete Linings of Water Mains....
Martin E. Flentje & Robert J. Sweitzer
Water Hammer Allowances in Pipe Design....S. Logan Kerr
Discussion....Vance C. Lischer, Fred G. Gordon & B. E. Payne
The Courts Consider Pipeline Breaks....John H. Murdoch Jr.

Water Resources Division

Saline Water Conversion....David Jenkins
Discussion....S. T. Powell
Reservoir Evaporation Control....Lloyd O Timblin Jr., W. T. Moran & W. W. Garstka
Weather Modification—Task Group Report....Burton S. Grant
Honolulu Water Supply....Edward J. Morgan

TUESDAY MORNING, May 14

Water Works Practice Committee—Open Session

Progress Reports of Committees
Butterfly Valves....Fred G. Gordon
Gate Valves....David Auld & L. E. Tabor
Meters....James G. Carns
Progress in Standardization of Water Pipe
Cast-Iron Pipe....Thomas H. Wiggin
Steel Pipe....H. Arthur Price
Reinforced Concrete Pipe....E. W. Whitlock
Joint Committee on Spillway Design....Thomas H. Wiggin

Water Purification Division

The Jar Test—A Review.................A. P. Black
Coagulant Aids.................J. M. Cohen
Radioactive Culture Media.........Gilbert V. Levin, Venton R. Harrison & Walter C. Hess
Automation and Remote Control of Chemical Feeders.................Paul Coffman
Organic Components in Water Causing Taste and Odor.................F. M. Middleton

TUESDAY AFTERNOON, May 14

Water Resources Policy and Development—General Session

The Oregon Water Law.................Fred Merryfield
New Jersey Water Supply Development.................*Governor* Robert B. Meyner, W. H. Baumer & Charles H. Capen
Planning—Key to Greater Utilization of Water Resources.................M. J. Shelton

WEDNESDAY MORNING, May 15

General Session

AWWA Specifications and the Certification Program.............Frank C. Amsbary Jr.
Proposed Amendments to the Constitution.................Harry E. Jordan
National Water Policy.................Abel Wolman
Water Works Planning in Great Britain.................G. M. Binnie
Panel Discussion—Highway Relocation Problems.................*Led by* H. B. Shaw, E. Jerry Allen, S. S. Anthony, J. J. Barr, E. A. Bell, E. W. Clark, Thomas W. Moses & A. R. Vollmer

WEDNESDAY AFTERNOON, May 15

Water Resources Division

Water—Wealth or Worry for America—Motion Picture....Cast Iron Pipe Research Assn.
Progress Reports of Committees
- Underground Waste Disposal and Control.................Lynn M. Miller
- Artificial Ground Water Recharge.................John J. Baffa

Water Works Management Division

Progress Reports of Committees
- Radio and Mobile Communications Facilities.................M. B. Cunningham
- Water Use in Fire Prevention and Protection.................A. A. Ulrich
- Compensation of Water Works Personnel.................Garvin H. Dyer
- Pension and Retirement Plans.................John G. Copley
- Job Classifications.................Robert S. Millar
- Water Use.................H. E. Hudson Jr.

Water Distribution Division

Greater Than Gold—Motion Picture.................Koppers Co., Inc.
Progress Reports of Committees
- Effect of Purification Methods on Water Main Carrying Capacity..........T. E. Larson
- Protective Coatings for Water Distribution Systems.................R. F. McCauley
- Oil-Line River Crossings.................M. B. Cunningham
- Reinforced Concrete Pipe.................E. W. Whitlock

Water Purification Division

Progress Reports of Committees
- Studies of Chromium and Cadmium Solubility and Toxicity............R. D. MacKenzie
- Research on Water Coagulation.................A. P. Black

Manganese Deposition in Pipelines.......................................A. E. Griffin
Specifications for Liquid Chlorine.......................................H. A. Faber
Specifications and Tests for Water Purification Chemicals............James E. Kerslake
Specifications for Fluorides...Oscar Gullans
Backflow Preventers...A. T. Dempster
Standard Methods for the Examination of Water, Sewage, and Industrial Wastes........
Michael J. Taras
Uniformity of Methods of Water Examination.......................Michael J. Taras
Effects of Synthetic Detergents on Water Supplies.....................Paul D. Haney
Analytical Methods for Detergents.......................................James C. Vaughn
Water Conditioning and Prevention of Corrosion.........................Rolf Eliassen

THURSDAY MORNING, May 16

Water Distribution Division

Lifelines for Civilization—Motion Picture.........American Concrete Pressure Pipe Assn.
Service Buildings..L. S. Finch
Service Trucks...Fred D. Jones
Panel Discussion—Setting Meters..............................*Led by* W. Victor Weir,
G. E. Arnold, James G. Carns, W. E. MacDonald & Marsden Smith
Panel Discussion—Cleaning and Relining Small Mains.................................
R. W. Fitzgerald, Frank Schwemler & Lewis B. Smith

Water Purification Division

Handling Liquid Alum...James E. Kerslake
Discussion...
Oscar Gullans, Norman E. Jackson, Leo Louis, David Lurie & Richard Ockershausen
Carbonation of Water-softening Sludge.................................F. A. Eidsness
Discussion...F. G. Nelson
Panel Discussion—Experiences in Applying Fluorides.............*Led by* John R. Baylis,
A. A. Bailey, E. L. Bean, A. P. Black, Marshall P. Crabill, A. E. Griffin,
James E. Kerslake, J. W. Krasauskas, H. C. Medbery, B. C. Nesin,
R. S. Phillips, J. C. Smith & J. C. Zufelt

THURSDAY AFTERNOON, May 16

Management Division—General Session

The 1957 Bond Market...George I. McKelvey
Problems in Personnel Recruiting..Milton Rosen
Wisconsin's Policy on Municipal Utility Taxation..........................A. P. Kuranz
Panel Discussion—Water Utility Earnings.........................*Led by* L. R. Howson,
Burton S. Grant, M. H. McGuire, E. M. Hawkins Jr., H. J. Graeser,
Claud R. Erickson, M. B. Whitaker & Fred Merryfield

Papers Scheduled at 1957 Section Meetings

THERE follows a summary listing of papers scheduled for presentation at 1957 Section Meetings. The dates of the Section Meetings from 1953 to 1957 and the locations for 1957 are listed on page 1617. Section officers who were elected at meetings held during 1957 are listed on page 2 P&R in the front of this issue. The programs are listed alphabetically by Sections, without regard to the date of presentation.

Alabama-Mississippi Section—October 20–23, 1957

Address of Welcome.......................................*Mayor* Laz Quave
Report from AWWA.......................................Lewis S. Finch
Public Relations From a Cashier's Viewpoint.......................................Francis P. Scott
Weather Modifications in Theory and Practice.......................................Irvin P. Krick
Panel Discussion—Water for Our Growing Cities...........*Led by* Phillip E. LaMoreaux, Melvin Williams & Walter B. Jones
Mississippi Water Rights Law.......................................Jack Pepper
Management of Municipal Utility Revenues.......................................Gerald R. Carter
Some Aspects of Providing Domestic and Fire Protection Service to Small Communities... C. M. McConaghy
Report of Safety in Water Works Operation.......................................Karl A. Woltersdorf

Arizona Section—April 4–6, 1957

Address of Welcome.......................................*Mayor* Richard G. Johnson
Use of Sewage Effluent in Agriculture.......................................Albert Oshrin & Neal Dye
  Discussion.......................................Dario Travaini
Chlorinator Control Apparatus.......................................Bruce Hedrick
Sand Trouble in Wells, Pumps, Tanks, and Mains—What Can Be Done About It?....... Phil J. Martin Jr.
Comparison of Sewage Treatment Methods.......................................H. W. Gillard
Stream of Life.......................................Howard E. Lyman
Variation of Water Quality in Arizona.......................................George Marx
Engineers' Dreams Are All Wet.......................................Emil Krall
Maricopa County Requirements for Backfill.......................................Cecil Overstreet
  Discussion.......................................Roy Hilbrant & John Rauscher
Demonstration of Pipe Joints...............George Bogs, A. W. Miller & R. J. McLean
Water Production From Watersheds.......................................George Barr
Possible Underground Water Supply in Northern Arizona...............J. Joseph Perkins
  Discussion.......................................Sam Turner
Types of Liquid Level Control.......................................R. M. Cushing
Accounting and Collecting Procedures.......................................E. J. Umbenhauer
Panel Discussion—Sewer Maintenance
  Effect of Garbage Grinders on Sewers.......................................Kenneth Scharman
  This Problem—Industrial Waste.......................................Arthur Pickett
  Photographic Inspection of Underground Structures.......................................A. A. Appel

California Section—Regional Meeting—April 26, 1957

Address of Welcome........*Mayor* Russell Hart
Response........M. J. Shelton
Water for California's Growing Cities........Max Bookman
Fundamentals of Corrosion in Water Utilities........F. O. Waters
California Cooperative Snow Surveys........Charles A. McCullough
Panel Discussion........*Led by* Gerald Jones
  Construction Equipment for Small Water Utilities........W. K. Foerster
  Office and Field Paper Forms........Caspar L. Winiger
  Regulatory Problems of Privately-owned Water Utilities........John D. Reader
  Sanitary Problems and Their Solution........Carl B. Johnston
  Administrative Practices for Small Water Companies........Patrick J. Maloney

California Section—October 30–November 1, 1957

The Attorney's Part in Multipurpose Water Development........Porter A. Towner
Supplemental Water Supply for the San Francisco Bay Area........William L. Berry
Conversion of Saline Water........Everett D. Howe
Water Supply in Santa Clara County........Mark E. Thomas
Techniques of Cable Tool Drilling vs Rotary Drilling........Roscoe Moss Jr.
A Rotary Drilled Well for the City of Long Beach........Frank T. Higgins
Well Photography—In Respect to Repair and Rehabilitation........C. H. Sorter
Well, an Engineered Structure or a Hole in the Ground........S. T. Guardino
Reconnaissance of Owens River Aqueduct Watershed........Fred A. Camp
Industrial Safety Regulations for Vehicles........V. L. White
Use of Red Lights on Public Utility Vehicles........Seth K. Martin
Service Laterals—Repair or Renew........William H. Eppinger
Water Works Material—Your Money's Worth........Ray W. Jones
Pipe Jointing and Pipe Joint Leaks........O. A. Goldman
Water Use During Construction—Problems and Solutions........
W. K. Foerster, John W. McBride, Carlyle Washburn & Frank W. Callahan
Gunite—Its Use in Reservoir Construction........Russell Kenmir
Variable Speed Motor Applications
The Economics of Meter Maintenance Programs........P. M. Robinson
Design of Water Rate Structure........Walter J. Cavagnaro
Financial Diagnosis for the Small Water Company........Allen D. Harper
Electronics and Public Utilities........Frank Twohy
Actinomycetes in Water Supplies........Kent Bartholomew
Consideration of Toxicity in Respect to Drinking Water Supplies....Herbert E. Stokinger
Water Quality From the Soil and Plant Relationship Viewpoint........L. V. Wilcox
Removal of High Concentrations of Hydrogen Sulfide From Water Supplies........
James Foxworthy
Air-Conditioning Water Use Regulations........Ralph M. Westcott

Canadian Section—June 17–19, 1957

General Water Works Problems—Guided Discussion........*Led by* W. D. Hurst
Design and Construction of Long Water Supply Lines........Louis R. Howson
Pipeline From Buffalo Pond Lake to Regina........A. Shattuck
Aids for Water Coagulation........A. E. Griffin & R. J. Baker
Distribution System Design........Lucien L'Allier
Distribution System Operation and Maintenance........K. E. Patrick

Microstraining and Its Applications in Water Clarification....................P. L. Boucher
Water Works Emergency Committee Progress Report......................D. B. Williams
Civil Defense Demonstration..C. D. Greater
Questions and Answers..A. E. Berry
Experience in Metropolitan Water Works Administration at Winnipeg........N. S. Bubbis
Some Aspects of Water Storage Reservoirs................................A. B. Patterson
A Survey of Water Purification Practice in Canada......................D. H. Matheson
Questions and Answers..A. E. Berry

Canadian Section—Maritime Branch—October 17–18, 1957

Microstraining in Water Clarification......................................P. L. Boucher
Panel Discussion—General Water Works Problems..................*Led by* F. R. Fraser
Fluoridation—Its Control and Headaches ....G. L. Renner
Guided Discussion—Management and Other Desk Problems........*Led by* J. W. Churchill
Metropolitan Organization for Essential Services..........................W. E. Moseley
Advantages of Metro Planning and Organization..........................J. F. MacLaren
Halifax-Metro Organization and Services................................G. T. G. Scott
Administration and Operation of Metro......................................J. R. Kaye

Chesapeake Section—October 30–November 1, 1957

Address of Welcome..Alvin C. Welling
Potomac River Basin Studies............................Byron Bird & Edwin E. Pyatt
Development of Proposed Water Resources Legislation in Delaware...George M. Worrilow
Research in Water Supply and Pollution Control............................Harry Faber
Use of Coordinated Daily Laboratory Tests........................Edward Scott Hopkins
Anne Arundel County's Problems..Paul L. Holland
Political Unification of Great Centers of Population....................Gerald W. Johnson
Establishing Fair Value in Water Rate Cases......Charles H. Kessler & Hugh H. Hunter
Conversion of a Reserve Raw-Water Tunnel for Distribution Purposes......John C. Geyer
Progress Report on the Specialty Board on Certification of Sanitary Engineers..............
Mark D. Hollis
Federal Inter-Agencies Activities Involved in Water Supply............M. Le Bosquet Jr.
McIlroy Analyzer Experiences........E. E. Bolls Jr., M. Joseph Willis & Jerome B. Wolff
Algae and Other Interference Organisms in the Chesapeake Bay Area........C. M. Palmer
Irrigation Use of Water...Luther B. Bohanan
Simplified Fluoride Distillation Method....................................Ervin Bellack

Florida Section—November 10–13, 1957

Address of Welcome...*Mayor* Haydon Burns
Response...Stanley Sweeney
The Challenge to Our Organizations......................................Emil C. Jensen
Penny-Wise Water...Lewis S. Finch
Selling Our Services to the Public......................................Morris M. Cohn
Lifelines for Civilizations—Motion Picture
Panel Discussion—Disposal of Softening Plant Sludge..........*Led by* Fred A. Eidsness,
David B. Preston, C. S. McKinney & E. C. Shreve Jr.
Hindered Settling in an Upflow Basin......................................J. D. Walker
Panel Discussion—Interpretation of Water Plant Analyses............*Led by* S. W. Wells,
Charles P. Roddy, Frank S. Little & Roy Heasley
Monitoring for Radioactive Fallout.................................Harry P. Kramer

Florida's Water Resources Law....John W. Wakefield
Effect of Sewage and Industrial Wastes on Water Quality and Treatment....
E. Sherman Chase
Pollution Study of Biscayne Bay....J. Neeland McNulty & Walter R. Lynn

Illinois Section—March 20–22, 1957

Address of Welcome....James W. Jardine
Impact of Water Use for Air Conditioning on Chicago Water Systems....H. H. Gerstein
Coliform Removal by Water Treatment Processes....Graham Walton
Public Relations Problems for Water Works Employees....Bert Johnson
University Cooperation....J. C. Dietz
Panel Discussion—Ground Water
  Construction and Maintenance of Rock Wells....E. L. Nordness
  Construction and Maintenance of Gravel Wells....Albert Sabo
  Water Well Production in Illinois....Robert T. Sasman
  Application of Submersible Pumps for Deep Wells....E. R. Warnicke
Designing for Future Water Demands....A. H. Gent
Panel Discussion—Surface Waters
  Development and Control of Impounded Water Supplies....J. R. Gardner
  Installation of Bascule Gates for Water Supply....H. L. Chastain
Mineral Quality of Illinois Rivers....T. E. Larson & Bernt O. Larson
Application of Electronics in Water Supply....Howard Jacoby
Oxidation-Reduction Potential Measurements....C. E. Margrave & James G. Weart
Breakdown Tests of Water Meters at Springfield....L. W. Hagel
Installation and Maintenance of Valves and Hydrants....L. F. Lindeen

Indiana Section—February 6–8, 1957

Address of Welcome....C. Everitt Robbins
Selection and Application of Centrifugal Pumps for the Water Works Industry....
Richard Kummer
Municipal Softening and Iron and Manganese Removal....Eskel Nordell
Practical Aspects of Polyphosphate Treatment of Municipal Water Supplies....
Herman A. Reda
Panel Discussion—All the Water You Want, When and Where You Want It?....
Led by Lewis S. Finch
  Can the Water Supply Industry Meet the Requirements of Today and Tomorrow?....
H. E. Jordan
  Trends in the Demand for Water in Indiana....B. A. Poole
  What Seasonal or Peak Loads Should a Water Utility Be Expected to Meet?....
H. H. Gerstein
  Controlling Seasonal or Peak Loads by Demand Meters and Charges, or by Use Restrictions....M. P. Hatcher
Development of a Master Plan to Meet Future Water Needs....L. H. Enslow
Our Approach to a Master Plan
  Fort Wayne, Ind....H. A. Kerby
  Michigan City, Ind....H. J. Draves
  Rockport or Newport, Ind....Donald Porter
  Mishawaka, Ind....Austin Klein

Iowa Section—October 16–18, 1957

Address of Welcome....A. B. Chambers
Response....P. F. Morgan

Operating Under A Union Contract....................Jack F. Culley
Missouri River Water Quality as Affected by Upstream Storage....................
M. E. Rew & Joseph F. Erdei
Industrial Development and Local Utilities....................T. E. Davidson II
Modern Customer Billing and Collecting Procedures and Equipment in Action
Don L. Bragg, John W. Prather, Robert L. Mason, & R. G. Carter
Radioactivity in Public Water Supplies....................R. L. Morris
Drought Effect on Impounded Supplies....................Jack Cleasby
Recent Developments in Research and Use of Coagulation Aids....................Jesse M. Cohen
Committee Reports—Water Rates, Main Extensions, Job Classifications....................
Led by Mark Driftmier, G. C. Ahrens, D. Y. Caldwell,
Marcus P. Powell & H. F. Seidel
Penny-Wise Water....................Lewis S. Finch
Iowa's New Water Law....................R. G. Bullard

Kansas Section—April 10–12, 1957

Water Problems and Legislation in Kansas....................Robert L. Smith
Water and Sewage Facilities for Kansas Turnpike....................Clifford Sharp
Public Relations and Your Job....................Harry L. Morris
Panel Discussion—Effects of the Severe Drought on Kansas Cities and How to Live
With It..........R. W. Cunningham, Carl Wortman, Bernard Budd & Don Overman
Address of Welcome....................*Mayor* A. E. Howse
Response....................B. H. Van Blarcum
The Water Works Industry in the Water Resources Picture....................Fred Merryfield
Construction Grants for Municipal Sewage Works....................Dwight F. Metzler
Two Years in Jordan....................Roger Lee
Consulting Engineer's Responsibility During and After Construction of Plant....................
Murray A. Wilson
Manufacturing and Laying of Asbestos-Cement Pipe....................E. W. Spinzig Jr.
Repair of Water Mains....................Luther L. Smith
The Importance of Water Works Records....................O. R. Green
Panel Discussion—The Question Box....................*Led by* Harley Lucas
G. Dorr Pelton, Orville Kuran, Karl J. Svaty & A. P. Flynn
Bargain Basement Water Rates....................J. W. Heiney
Use of Activated Silica as a Coagulant Aid....................V. W. Langworthy

Kentucky-Tennessee Section—September 23–25, 1957

Address of Welcome....................*Mayor* Andrew Broaddus
Response....................R. L. Lawrence Jr.
Penny-Wise Water....................Lewis S. Finch
Water and Sewage Treatment in Emergencies....................H. P. Cramer
Utility Accounting Practices....................W. G. Thomas & Sterling S. Gregory
Butterfly Valves....................Henry C. Schwenk
Iron and Manganese Removal....................E. J. Connelley Jr.
Effects of Storage Impoundments on Water Quality....................M. A. Churchill
New Developments in Taste and Odor Control in Kentucky and Tennessee..E. A. Sigworth
Coagulation Experiences....................Percy Johnson
Panel Discussion—Plant and Distribution Problems....................*Led by* Hunter Owen
Distribution Problems....................Joe W. Lovell
Plant Problems....................John Quinn
Plant Expansion—Louisville Water Company....................William H. Richardson

Michigan Section—September 25–27, 1957

Address of Welcome..*Acting Mayor* Louis C. Miriani
Response...W. E. Smith
News From the Field......................................John E. Vogt
History of Water Treatment in Detroit....................William M. Wallace
Detroit's New Northeast Water Filtration Plant
General Description......................................A. C. Michael
Chemical Treatment, Mixing, Flocculation and Sedimentation...........G. I. Stormont
Rapid Sand Filtration Rates, Equipment, and Instrumentation..........Douglas Feben
Symposium on Maintenance
Fire Hydrants and Policy on Fire Meters..................Tony Eikey
Pavement Breaking and Repairs............................Joseph M. Rogeven
Emergency Repairs in System..............................Albert Sabo
Elevated Tanks...E. D. Barrett
Handling and Feeding of Chemicals
Alum...George Hazey
Fluoride...W. L. Harris
Lime...John F. Dye
Millipore Filter in Bacteriological Analysis.............Irving L. Dahljelm
Filtration Rates...Herbert E. Hudson Jr.
Bacterial Loadings on Water Treatment Plant..............Graham Walton
The Wayne County Water Supply
The Development of the System............................George Bingham
Detroit River Survey.....................................Frank P. Coughlan Jr.
Functional Design of the Wayne County Filtration and Pumping Plant..Alfred W. Sawyer
Winchester Village Water Supply..........................Robert H. Zumstein
Design of Sheetpile Retaining Walls and Trench Bracing...............William S. Housel
Population Forecasts.....................................Paul M. Reid
Cost of Projects and Interest Rates......................J. Dean Stanley

Missouri Section—September 29–October 1, 1957

Address of Welcome.......................................*Mayor* Raymond R. Tucker
Penny-Wise Water...Lewis S. Finch
Panel Discussion—Pollution (Control and Trends) on Mississippi and Missouri Rivers.... *Led by* Allen H. Wymore
Pollution Abatement Outside Missouri.....................Vance C. Lischer
Pollution Abatement in Missouri..........................Jack K. Smith
Future Stream Flows......................................Thomas F. Maher
Shell Oil Industrial Waste Treatment.....................L. C. Burroughs
Recent Developments in Water and Sewage Pipe Joints......John Steencken & Bart Bretz
How and When to Select a Consulting Engineer.............Hueston M. Smith
Water Waste and Leak Detection on Distribution System
St. Louis Techniques.....................................Carl F. Buettner
Value of Pitometer Survey................................W. D. Hudson
Facility Expansion of St. Louis Water Division...........C. B. Briscoe
Water Meters and Shop Practice
Testing and Calibration..................................David J. Ford
Maintenance..John L. Ford
Epoxy Paints for Meters..................................F. Weber
Panel Discussion—Adequate Water During Drought Periods......*Led by* Leonard Dworsky
Action of Missouri State Highway Commission Regarding Reimbursement of Utilities as Per Revised Highway Act.......Rex Whitton
Long-Range Planning of Water and Sewerage Facilities.....Eugene Meyer
Storage Tank Inspection and Maintenance..................K. O. Kessler
Measuring of Remote Water Levels.........................Walter Messner

Montana Section—April 4–6, 1957

Address of Welcome....................*Mayor* Russel Conklin
Response....................Verne Reed & Ben Chestnut
Symposium on Waste Disposal....................*Led by* C. W. Brink, John Hazen, C. A. Cromwell, R. L. Kimmons & N. H. Sandberg
Legal Responsibilities of Water and Sewage Utilities....................James Battin
The Use of the McIlroy Analyzer on Water Distribution Systems....................Charles Barker
Current Happenings in Legislature....................Alfred Klingler
The Water Works, Pacesetter of Progress....................Paul Weir
Industrial Development With Regard to Water....................Perry Roys

Nebraska Section—April 24–26, 1957

Address of Welcome....................*Mayor* Bennett Martin
Response....................Carl L. Fisher
Season and Special Utility Rates....................Del A. Blatchford
Atomic Energy Development....................R. N. Slinger
University of Nebraska Conference Reports....................Robert W. Mills
1903 Utility Construction Costs....................Ernest Hansen
Cement-Lined Pipe—Its Benefits and Use....................Bart G. Bretz
Review of Laws Affecting Water Resources....................Robert Perry
Sacred Cows....................Maurice E. Cole
The Use of Demand Metering for Commercial Electric Accounts....................Albert Learned
Review of Federal Sewage Law No. 660....................Glen J. Hopkins
Status of 1957 Legislation....................Al G. Wurst

New Jersey Section—October 24–26, 1957

New Jersey Water Supply....................Charles H. Capen
Full Development of Newark's Pequannock River Water Supply.................... Arthur J. Simpson G. Gale Dixon & Herbert L. Kauffmann
Preliminary Report of the Geology and Ground Water Resources of Cape May County, N.J. Harry E. Gill
Successful Control of an Excessive Lawn-sprinkling Load....................Robert M. Grieve
The Use of Audio Tones in Water Systems....................L. C. Menkes
Committee Report—The Effect of Temperature on Backwash Rates of Anthrafilt Media.. Peter E. Pallo
Committee Report—The Status of the Membrane Filter Technique as of 1957.................... Ernest R. Segesser
Committee Report—The Dorr-Clone and Its Application to Lime Treatment.................... Peter E. Pallo & David R. Horsefield
Safeguarding Water Supplies in the Atomic Age......William H. Aaroe & Byron E. Keene
Comparison of Taste and Odor Problems and Controls in New Jersey and the United States....................E. A. Sigworth
Taste and Odor Problems and Controls....................Attmore E. Griffin
The Prudent Man....................John H. Murdoch Jr. & Henry A. Riddle

New York Section—April 10–12, 1957

Discussion of Matching Funds and Surplus Property Available to Water Departments for Civil Defense....................Raymond Barbuti
Panel Discussion—Storage on the Distribution System..........*Led by* George E. Symons
The Economics of Storage Versus Main Strengthening in a Distribution System......... Donald E. Stearns
Various Types of Storage Facilities....................Robert G. Holzmacher
Comparison of Elevated Storage Versus Ground Storage..........Samuel C. McLendon

Aerial Surveys as Applied to Watershed and City Areas................Maurice J. Perrier
The Effect of a Synthetic Detergent on the Chlorination of Water.........Charles D. Gates
Can the Water Works Industry Attract and Hold Competent Personnel?.................
William T. Ingram
The Water Works, Pacesetter of Progress.................................Paul Weir
Round Table Conference...............................*Led by* Angus D. Henderson

New York Section—September 11–13, 1957

Basic Hydraulics..George E. Symons
Hydraulics in the Distribution System..............................Robert J. Sweitzer
The Use of Fire Hydrant Flow Tests..................................George F. Hoag
The Successful Control of an Excessive Lawn-sprinkling Load...........Robert M. Grieve
Iron and Manganese in Water Supply...............................Thomas M. Riddick
Liquid Alum Application...George H. Straub
Round Table Discussion...............................*Led by* Donald E. Stearns

North Carolina Section—November 11–13, 1957

Address of Welcome...*Mayor* W. G. Enloe
Raleigh's Utilities...E. M. Johnson
Pilot Plant Research at Cone Mills......................R. H. Souther & Tom Alspaugh
Panel Discussion—Impact of Federal Aid Highways on Utilities Systems
Municipalities................................Tom Z. Osborne & Leonard P. Bloxam
State Highway Commission...W. H. Webb Jr.
Summary and Discussion..John T. Morrisey
The Seven City Water Project...................................George A. Covington
Color Removal in Municipal Sewage Treatment Plants...............Nelson L. Nemerow
Pneumatic Controls for Water and Sewer Plant Instrumentation.............David Tobin
Sizing of Water Meters.............................Charles Floyd & Paul McCullough

North Central Section—September 25–27, 1957

Water and Sewage Pump Maintenance...............................David Gallagher
Use of Plastic Pipe in Water Distribution........................Howard M. McDaniel
Federal Aid for Sewerage Construction....................................Paul Bolton
Design Features of Grand Forks Water Plant Addition................Allan H. Wymore
Discussion...Robert M. Jenson
Design and Operation of Small Water Plants........................Johnny Klingenberg
Discussion......................................Ralph Dwelle & Carl Torkelson
Steel Water Tank Maintenance and Repair...............................Ted E. Welk
Central Missouri River Water Quality Investigation..........................Joe K. Neel
Discussion...........William Yegen, Robert Shaw, Don Wessel & James L. Jenson
Sewage Treatment Facilities for Williston [N.D.].......................Herbert Arnold
Reports from State Health Departments..
Charles E. Carl, Frank L. Woodward & W. L. Van Heuvelen
Panel Discussion—Water Plant Operation.......................*Led by* John A. Oakey
Panel Discussion—Sewage Plant Operation.................*Led by* George J. Schroepfer
Penny-Wise Water..Lewis S. Finch
Recarbonation in Water Treatment...................................Dean E. Colvin
Discussion.....................................Glenn Berg & Clayton M. Bach
Public Works Development in New Subdivisions.........................Edward J. Booth

Ohio Section—September 18–20, 1957

Address of Welcome....*Mayor* Charles P. Taft
Water Quality, Monitoring Project....D. A. Robertson
Finance Operation, Billing, and Collection....Charles T. Rupert
One More Pipe Size....A. M. Friend
New Chemicals Used in Water Treatment....Leo Louis
Important Features of the New Water Supply at Columbus....Paul Laux
General Discussion of Plant Operation and Problems—A Discussion....*Led by* Robert Holt
New Construction at Mentor, Ohio, and Expanding Water Service in Western Lake County
W. Robert Bowman
Present Day Factors Tending to Limit the Financing of New Construction..Alfred LeFeber
Membrane Filter....Dan Enright
Control of Chlorination....R. J. Baker & A. E. Griffin
Water Main Cleaning and Coating....K. P. Stearns
Current Research Activities of the Association of American Soap and Glycerine Producers
F. J. Coughlin
A 1957 Look at Coagulation and Coagulants....R. W. Kirkconnell
Extension of 48-in. Concrete Water Main in Abandoned City Subway....Harry Rimmer
New Tyton Joint for Cast-Iron Pipe....P. K. Farrington
Satisfying Peak Demands During the Summer....Frank J. Schwemler
Reclamation of Lime....L. C. Huffman

Pacific Northwest Section—May 2–4, 1957

Address of Welcome....Gerrit VanderEnde
Water Resources of the Future....Fred Merryfield
Panel Discussion—Water Requirements for Industry and Expanding Population
Pulp and Paper Industry....Merrill Robison
Canning Industry....Virgil O. Scott
Cities and Water Districts....C. V. Signor, James R. Baun & J. E. Morrison
Panel Discussion—Development of Surface Supply
Capilano Dam....K. E. Patrick
Tolt River Supply....J. Ray Heath
Union River Dam....John W. Cunningham
Bull Run Dam No. 2....H. Loren Thompson
Microstraining....G. R. Evans
Development of Underground Supply
Ranney Wells....John R. Wallace Jr. & Robert A. Yale
Deep Wells....H. S. Baarslag Jr. & Richard W. McCann
Tacoma's Supply and Distribution System....W. A. Kunigk
Cathodic Protection....N. Kerry Patterson & Robert L. Lee
Demonstration of Pipe Locators, Pipe Tapping, Meter Testing, and Radio Communication
A. J. Benedetti & S. B. Smith
Electrical Supervisory Control....John L. Green, Marvin H. Schroeder & Sigurd Turnquist
Tacoma Reservoirs....George E. Hopkins

Pennsylvania Section—June 12–14, 1957

Panel Discussion—Water Works Practice
Management....Wendell R. LaDue
Distribution....Samuel S. Baxter
Legal Aspects....William H. Markus

Panel Discussion—Rehabilitation—Pittsburgh Water Works
General.......John A. Murphy
Cleaning Basins and Mains.......Morris Wolf
Clarification and Purification.......Robert Morris
Pumping Station Electrification.......E. F. Twomey
Theories of Adsorption With Activated Carbon.......John W. Hassler
Membrane Filter vs MPN Method for Coliform Determination.......R. B. Adams
Relation of Radioactive Substances to Water Supply.......Simon Kinsman
Dramatization—A Typical Rate Case.......*Led by* Jay H. Eisaman

Rocky Mountain Section—September 23–25, 1957

Address of Welcome.......Stanley J. Leland
Coliform Removal in Water Treatment Processes.......Graham Walter
Ditonite Filters.......R. C. Platt
Problems Arising From Radioactive Fallout From Nuclear Detonations Regarding Watershed or Reservoir Water Supplies.......P. W. Jacoe
Reservoir Evaporation Control.......Lloyd Timblin
Customer Complaints.......Jack Maguire
Service Policy to Fringe Areas.......Thomas Eaton
Water Main Extension Policies to Fringe Areas vs Local Areas.......Sid Nichols
Automation and Application of Electronics in the Utility Field.......Henry Prechtel
Personnel Developments, Salary Scales, Recruiting, and Training.......Robert S. Millar
Factors in the Design of Chlorination Stations as Regards Size, Safety, Operation, Control, and Maintenance.......John Strait
Safety Manual of AWWA.......Tom Eaton

Southeastern Section—March 17–19, 1957

Address of Welcome.......*Mayor* W. McG. Morrison
National Association Affairs.......Paul Weir
Southeastern Section Affairs.......Carl C. Lanford
Sampling and Testing Drinking Water.......Elizabeth McEntire & A. T. Storey
The Bushy Park Water Development.......Arthur Field & Francis B. McDowell
Customer Relations.......Allan Mustard
Panel Discussion—Selecting Proper Size Meters.......*Led by* Wm. R. Wise, Harry J. Siebert, Charles Floyd Jr. & Alan McC. Johnstone
Control and Instrumentation Systems.......Robert C. Kauffman
Symposium—Operator Recruiting, Training, and Certification.......W. A. Hardenbergh & Raymond J. Faust
Development of Rural Public Water Supplies.......J. M. Roberts & Riley Milam

Southwest Section—October 13–16, 1957

Address of Welcome.......*Mayor* Allen Street
Response.......Karl Hoefle
The Oklahoma City Water Supply—Present Water Works System.......Frank S. Taylor

Research on Taste and Odor..J. K. G. Silvey
Central and Southeast Oklahoma Water Supply and Canal Project..............Guy Treat
Evaporation Reduction Studies on Lake Hefner, Oklahoma City, Okla......................
M. G. Barclay, L. O. Timblin Jr., Bernard E. Berger,
S. K. Jackson, Stuart D. Whitford & J. K. G. Silvey
Cloud Seeding and Long-Range Weather Forecasting in Water Planning......Newt Stone
Discussion.............................M. B. Cunningham, Tom Amiss & Karl Hoefle
A New Standard of Precision in Microfiltration and Analysis—Motion Picture............
Millipore Filter Corp.
Aerial Mapping..Daniel Kennedy
Panel Discussion—Pollution Control of Water Supply Reservoirs.........................
Loyd F. Pummill, Glen T. Kellogg, John E. Trygg & Henry L. Dabney
Frontiers of Science Foundation of Oklahoma, Inc. ....James G. Harlow
Panel Discussion—Distribution System Problems.................*Led by* Henry Graeser,
Ralph Hardy & R. B. Rau
Value of Inventory and Accounting Controls in Water Works Operation....Jack Wilson
Safety First?...Sam Wantland
Discussion..Harvey G. Freehauf

Virginia Section—November 6–8, 1957

Panel Discussion—Liquid Alum......S. M. Hodges, H. E. Lordley & R. W. Ockershausen
A New Method of Fine Straining for Water Supplies........................G. E. Evans
Public Information Activities...Fred Merryfield
Discussion of Short School for Operators................................H. E. Lordley
Discussion of Operators Certification Program............................C. G. Haney
Blacksburg-Christianburg—V.P.I. Water Project....................W. Martin Johnson
Panel Discussion—Accident Prevention........X. D. Murden, F. H. Miller & Donald Cook
Bacterial Removal from Water Supplies by Use of Ion Exchange Resins..................
W. A. Parsons & J. J. Blair III
Panel Discussion—New and Old Water Plant Construction in Virginia...................
Brent Ramsburg, F. L. Showalter & R. D. Wright
Disposal of Radioactive Wastes......................................J. M. Morgan Jr.
The Relationship Between Public Water Supplies and Planning and Economic Development in Virginia...W. H. Caldwell
The People Business or Just Plain Folks............................Walter A. Flick

West Virginia Section—October 23–24, 1957

Williamson Settling Basin..W. S. Staub
Flood Damage—Tug and Big Sandy Rivers...............................Glen Fortney
Coagulation and New Coagulant Aids...............................R. W. Kirkconnell
Use of Chlorine and High Residuals......................................John Millar
National Representative—AWWA..................................Wendell L. LaDue
Mud Tub—Demonstration of Corrosion.................................A. E. Erickson
Membrane Filter...T. J. Blair III
Water Treatment for Air Conditioning....................................R. G. Dalbke
A Dollar and Sense Approach to Corrosion Control...........................W. J. Reese
Demineralization of Water..Howard E. Frazer

Wisconsin Section—September 4–6, 1957

Address of Welcome........*Mayor* Frank P. Zeidler
New Techniques in the Location of New Sources of Water........Robert Spanski
Recharging Water Bearing Formations........O. J. Muegge
Turbine Pumps as Boosters........Donald Johnson
Pumping Systems Without Elevated Storage........Douglas G. Maxwell
Underwriters' Interest in Fire Protection........John Wilkinson
Sizing Water Service Piping........Arthur Rynders
Mobile Communications in Water Utilities........Nathan Boruszak
Water Requirements for Air Conditioning........Guy R. Scott

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Section Meetings—1953–1957

Section	*1953*	*1954*	*1955*	*1956*	*1957*	*Meeting Place—1957*
Alabama-Mississippi	Oct. 4–7	Oct. 24–27	Oct. 30–Nov. 2	Oct. 21–24	Oct. 20–23	Biloxi, Miss.
Arizona	Apr. 16–18	Apr. 22–24	Apr. 14–16	Apr. 5–7	Apr. 4–6	Mesa, Ariz.
California	—	Apr. 9*	Apr. 15*	Apr. 13*	Apr. 26*	Santa Monica, Calif.
	Oct. 27–30	Oct. 26–29	Oct. 25–28	Oct. 23–26	Oct. 29–Nov. 1	San Jose, Calif.
Canadian	Apr. 6–8	Apr. 12–14	Apr. 18–20	Apr. 23–25	Jun. 17–19	Winnipeg, Man.
	Sep. 21–22†	Oct. 4–5†	Oct. 17–18†	Oct. 15–16†	Oct. 17–18†	Halifax, N.S.
Chesapeake	Oct. 28–30	Oct. 27–29	Oct. 26–28	Oct. 24–26	Oct. 30–Nov. 1	Washington, D.C.
Cuban	Dec. 3–5	—	Dec. 1–3	Nov. 29–Dec. 1	§	—
Florida	Oct. 11–13	Nov. 7–10	Nov. 6–9	Nov. 11–14	Nov. 10–13	Jacksonville, Fla.
Illinois	Mar. 18–20	Mar. 17–19	—	Mar. 21–23	Mar. 20–22	Chicago, Ill.
Indiana	Feb. 11–13	Feb. 10–12	Feb. 9–11	Feb. 8–10	Feb. 6–8	Indianapolis, Ind.
Iowa	Oct. 14–16	Oct. 13–15	Oct. 19–21	Oct. 24–26	Oct. 16–18	Des Moines, Iowa
Kansas	Apr. 22–24	Apr. 7–9	Apr. 13–15	Apr. 4–6	Apr. 10–12	Wichita, Kan.
Kentucky-Tennessee	Sep. 21–23	Sep. 20–22	Sep. 12–14	Sep. 17–19	Sep. 23–25	Louisville, Ky.
Michigan	Sep. 3–4	Sep. 15–17	Sep. 14–16	Sep. 12–14	Sep. 25–27	Detroit, Mich.
Missouri	Sep. 27–29	Sep. 26–28	Sep. 25–27	Sep. 30–Oct. 2	Sep. 29–Oct. 1	St. Louis, Mo.
Montana	Apr. 24–25	Apr. 23–24	Apr. 29–30	Apr. 6–7	Apr. 4–6	Great Falls, Mont.
Nebraska	Apr. 16–17	Apr. 22–23	Apr. 13–15	Apr. 11–13	Apr. 24–26	Lincoln, Neb.
New England	—	—	—	—	—	—
New Jersey	Oct. 22–24	Nov. 4–6	Oct. 20–22	Oct. 18–20	Oct. 24–26	Atlantic City, N.J.
New York	Apr. 16–17	Apr. 22–23	Apr. 20–22	Apr. 18–20	Apr. 10–12	Elmira, N.Y.
	Sep. 9–11	Sep. 9–10	Sep. 7–9	Sep. 12–14	Sep. 11–13	Upper Saranac Lake, N.Y.
North Carolina	Nov. 9–11	Nov. 8–10	Nov. 14–16	Nov. 12–14	Nov. 11–13	Raleigh, N.C.
North Central‡	Sep. 1–5	Oct. 6–8	Oct. 5–7	Sep. 12–14	Sep. 25–27	Fargo, N.D.
Ohio	Spe. 10–11	Sep. 22–24	Sep. 21–23	Sep. 19–21	Sep. 18–20	Cincinnati, Ohio
Pacific Northwest	Apr. 16–18	—	May 19–21	Apr. 26–28	May 2–4	Tacoma, Wash.
Pennsylvania	Jun. 17–19	Jun. 23–25	May 4–5	Apr. 3–5	Jun. 12–14	Bedford, Pa.
Rocky Mountain	Sep. 21–23	Nov. 9–10	Sep. 19–21	Nov. 26–28	Sep. 23–25	Santa Fe, N.M.
Southeastern	Mar. 23–25	Mar. 29–31	Mar. 20–23	Mar. 18–21	Mar. 17–19	Charleston, S.C.
Southwest	Oct. 18–21	Oct. 17–20	Oct. 16–19	Oct. 14–17	Oct. 13–16	Oklahoma City, Okla.
Virginia	Nov. 4–6	Nov. 3–5	Nov. 3–5	Nov. 7–9	Nov. 6–8	Roanoke, Va.
West Virginia	Sep. 3–4	Nov. 8–9	Oct. 20–21	Oct. 31–Nov. 2	Oct. 23–24	Wheeling, W.Va.
Wisonsin	Sep. 22–24	Sep. 28–30	Sep. 21–23	Sep. 26–28	Sep. 4–6	Milwaukee, Wis.

* Regional meetings. † Maritime Branch. ‡ Formerly Minnesota Section. § Meeting Canceled.

Section Membership at Time of, and Total Attendance at, Section Meetings—1953–1957

Section	1953		1954		1955		1956		1957	
	Membership	Attendance	Membership	Attendance	Membership	Attendance	Membership	Attendance	Membership	Attendance
Alabama-Mississippi	177	182	189	311	206	257	219	318	224	307
Arizona	72	41	76	199	68	157	77	156	84	234
California§	1,084	1,126	1,193	1,709	1,291	1,037	1,378	1,253	1,451	1,225
Canadian§	581	617	608	848	629	714	663	816	708	500
Chesapeake	247	224	248	210	258	211	267	191	288	228
Cuban	72	32	69	‖	54	*	52	43	62	‖
Florida	327	287	328	305	342	306	355	331	361	399
Illinois	482	407	504	474	527	‡	557	468	589	474
Indiana	330	386	332	399	392	475	409	421	478	499
Iowa	121	178	133	191	137	286	149	220	181	282
Kansas	206	170	220	191	229	208	237	236	239	217
Kentucky-Tennessee	186	203	189	294	201	259	221	317	252	317
Michigan	349	164	386	263	411	236	435	278	471	341
Missouri	189	242	198	260	206	230	228	275	238	306
Montana	58	107	55	117	57	76	54	84	61	132
Nebraska	82	224	95	200	94	164	103	183	109	156
New England	218	†	218	†	225	†	233	†	248	†
New Jersey	414	318	436	340	435	313	463	351	505	336
New York§	741	355	805	420	826	315	851	429	882	458
North Carolina	188	294	191	255	202	281	232	326	224	305
North Central#	229	166	241	179	238	162	260	157	278	177
Ohio	403	252	445	406	468	251	482	253	508	281
Pacific Northwest	345	346	441	‡	440	293	438	304	507	358
Pennsylvania	455	204	465	234	493	255	516	295	558	235
Rocky Mountain	156	125	170	100	171	94	186	164	237	152
Southeastern	203	205	246	313	267	325	278	319	300	335
Southwest	938	803	945	681	1,047	850	1,086	889	1,133	784
Virginia	179	226	188	230	192	237	207	233	213	241
West Virginia	102	120	103	212	100	152	104	126	105	195
Wisconsin	181	288	182	316	190	291	199	296	206	340

* No record of attendance.
† No regular meeting scheduled. Membership given as of dates of conferences.
‡ Regular meeting canceled. Business meeting held at annual conference.
§ Only one of section's meetings recorded here.
‖ Meeting canceled.
Formerly Minnesota Section.

Subject Index

A

Pagination: Jan. 1–88; Feb. 89–224; Mar. 225–368; Apr. 369–504; May 505–696; Jun. 697–824
Jul. 825–968; Aug. 969–1106; Sep. 1107–1238; Oct. 1239–1370; Nov. 1371–1506; Dec. 1507–1638

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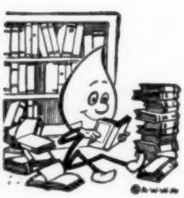
Pagination: Jan. 1-88; Feb. 89-224; Mar. 225-368; Apr. 369-504; May 505-696; Jun. 697-824
Jul. 825-968; Aug. 969-1106; Sep. 1107-1238; Oct. 1239-1370; Nov. 1371-1506; Dec. 1507-1638



Author Index

Binding the Year's Journals

Through the cooperation of the Library Binding Institute, an organization of binderies which specializes in binding publications into volumes, arrangements have been made to give information and assistance to AWWA members who want to have their JOURNALS bound. This work may be done in accordance with standards of materials and construction required for durability, service, and accessibility by college, reference, and public libraries. The American Library Association and the Library Binding Institute have cooperated in promulgating "Minimum Specifications for Class A Library Binding" based on research and production and performance experience

A committee of the American Library Association has certified responsible and reliable library binderies which have proved able to meet these specifications. To obtain standard quality binding, simply request Class A binding at any certified bindery. In obtaining price quotations, state the three dimensions of the volume.

Names and addresses of certified binderies in your area are available from the Library Binding Institute, 10 State Street, Boston, Mass. Before sending copies to the bindery:

1. Check for missing issues and check each issue for defects, missing pages, etc. Be sure to include the volume index.

2. Tie the twelve issues together carefully so that nothing is crumpled or torn.

3. Write out definite instructions giving your preferences on the following points:

    a. Color of binding (one of the following standard colors should be selected: dark green, dark blue, black, brown, or medium red).

    b. Whether the advertising sections and/or paper covers are to be bound into the volume.

    c. An exact copy of the text to be lettered in gold on the backbone. A common form is:

Journal—1¾ in. from top	Vol. 49—4¼ in. from bottom
AWWA—2¼ in. from top	1957—3¾ in. from bottom

    d. If you have had JOURNALS bound before and want your set to match as closely as possible, send a previous volume as a sample. If you want an approximate match, send a "rubbing" of the lettering on a previous volume and indicate the color.

If satisfactory arrangements cannot be made, or if there is any difficulty, advise the AWWA office and steps will be taken in cooperation with the Library Binding Institute to assure you proper service.

By arrangement with AWWA, University Microfilms, 313 N. First St., Ann Arbor, Mich., is making a microfilm edition of the JOURNAL available to regular subscribers at a price comparable with the cost of library binding. The cost of the microfilm edition of the 1956 volume was $8.90.

Journal

AMERICAN WATER WORKS ASSOCIATION

VOLUME 49 • 1957

AMERICAN WATER WORKS ASSOCIATION
Incorporated
2 Park Ave., New York 16, N.Y.

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Percolation and Runoff

P&R is 10 years old! So, too, of course, not are, but is Editors Anonymous—the disorganization of un-identified contributors of material herein converted into the language of "the 10-year-old." And if P&R's anniversary * is more to be observed than celebrated, let it not be so with Editors Anonymous's, for to be an EA is to be unobserved. In celebration, then, of the first full decade of Editorial Anonymity, we (the strictly editorial "we," at least) who profit by EAism wish to salute all 145 anonyms, living and dead, who have provided the wherewithal for P&Rticles past and present. Over the years we have taken advantage of this season of peace and goodwill to risk disanonymizing the currently active members of this super-secret sort of society, the better to thank them for their contributions. And with this tenth Christmas upon us, we venture once more to unbeard our Santa Cli and to note not only the extent of their present responsibility for P&R, but the number of years during which they have incognitoed our lines.

With the completion of a full decade of Editors Anonymous, it has been necessary to establish a new classification of membership—*Fully Decadent*—to do justice to three whose *Incurability* has been manifest from the very beginning of P&R. Meanwhile, it will be well to point out again that those listed below as *Incurables* can't help but help us; the *Deetees* frequently have; the *Shakes,* occasionally; and the *Jitters,* once or twice, whether they have known it or not. The powers ascribed to them, of course, are the measure of their years of helpfulness:

Fully Decadent

E. L. Filby[10] J. M. Wafer[10]
P. S. Wilson[10]

Incurables

C. H. Capen[9]	M. D. Saunders[1]
D. C. Colebaugh[8]	E. A. Sigworth[9]
M. J. Harper[5]	H. J. Spaeder[2]
W. R. LaDue[7]	R. L. Tyler[6]
C. E. Painter[5]	Henry Wilkens[5]

Deetees

N. M. DeJarnette[6]	Fred Merryfield[2]
D. N. Fischel[9]	A. S. Metcalf[1]
R. E. Hansen[6]	D. B. Williams[6]

Shakes

H. A. Faber[2]	A. E. Griffin[2]
M. E. Flentje[6]	G. E. Symons[8]

* The picture of Willing Water carrying the anniversary torches is provided by courtesy of the Maritime Branch of AWWA's Canadian Section, which had the cake baked to celebrate its own tenth meeting and then borrowed unbeknownst.

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Jitters

H. W. Badley[1]	John Kleinhenz[4]
Don Berkow[1]	G. J. Manahan[3]
A. P. Black[6]	Jack McKee[1]
M. T. Bramman[2]	Mildred Merryfield[1]
J. W. Cramer[1]	L. S. Morgan[2]
J. W. Finney[1]	X. D. Murden[2]
D. J. Ford[1]	H. J. Ongerth[2]
J. L. Ford[1]	B. E. Payne[5]
Philip Grannan[2]	H. G. Reichardt[2]
L. W. Helmreich[1]	J. S. Rosapepe[4]
W. T. Ingram[2]	G. R. Scott[3]
R. L. Jones[2]	Brian Shera[2]
W. A. Welch[4]	

To all the helpful—the 48 of '57 and the almost 100 others since '48, not to mention the readers of P&R, severally —*Merry Christmas!* And not only to them, but to ourself via their continued helpfulness, *Happy New Year!*

Speaking of P&R reminds us of the notice in the February issue of the *Consulting Engineer* concerning the development at the USSR Academy of Sciences of an electronic computer that automatically translates texts from English into Russian. Knowing that a considerable number of copies of the JOURNAL go to Russia—and even to the Academy where the robot is located—we can't help but wonder what would come out if one of the more abstruse P&Rticles were fed into the translator—or was that what happened to Zhukov?

AWWA's certification program is still a-borning, primarily because its birth is being attended by many more pangs—legal and administrative—than were premeditated at its conception. The obstetrical target is now the last week in January 1958, when the Board of Directors will give its attention to slapping some life into the recommendations delivered by its General Policy Committee. In the meantime, to make certain that the new baby has the very best chance not only of survival, but success, its parents and godparents are busy working out solutions to the problems that will face it. Comes January, comes cigars, we hope, but right now AWWA paces uncertified.

T. T. Quigley

R. C. Clement

Wallace & Tiernan Inc. has announced the promotion of personnel in its equipment divisions, effective Jan. 1, 1958. Thomas T. Quigley is to be director of equipment divisions; Russell C. Clement, director of sales for chlorination and chemical-feeding equipment; and Donald N. Hale, production manager. Mr. Quigley joined the firm in 1940 and has served most recently as executive assistant to the vice-president. Mr. Clement, with the company since 1924, was manager of field sales and service. Mr. Hale has been with Wallace & Tiernan since 1936, and has had experience in sales, sales engineering, and production.

A. R. Fisher has been named chairman of the board of Johns-Manville Corp., succeeding Leslie M. Cassidy, who retired. Mr. Fisher continues as president and director, offices which he has held since 1951. Clinton B. Burnett has been elected executive vice-president.

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Linn H. Enslow, editor of *Water & Sewage Works* magazine, New York, died at his farm in Dublin, Va., Nov. 3, 1957. He was 66. Born at Richmond, Va., in 1891, he received a BS in chemistry from Virginia Polytechnic Institute in 1912 and became assistant works chemist with General Chemical Co., Baltimore, Md., the same year. In 1913 he engaged in postgraduate studies in chemistry and electrical engineering at Johns Hopkins and the following year undertook part-time work with the Maryland Health Dept. In 1915 he became assistant chemist on a full-time basis with the department, and 2 years later was placed in charge of the water and sewage laboratory.

During his service with the department he was associated with Abel Wolman in an intensive study of the application of chlorine to the water supplies of Maryland. From this study it was learned that the observed chlorine residual in treated water could be relied on as an indicator of the efficiency of the process. Actually, this study has become the foundation on which modern water chlorination is grounded.

In 1918 he became chemist in charge of the Spartanburg, S.C., filtration plant and the next year accepted a post as chemist at the Panama Canal, where he also supervised the filter plant. He returned to Virginia in 1920 to become assistant engineer with the State Health Dept., leaving after 5 years to take a position as research engineer with The Chlorine Institute, New York. In 1931 he was named editor of *Water & Sewage Works.*

An Honorary Member of AWWA (joined in 1918), he served as director and president, and was chairman of the Publication Committee for many years. In recognition of his services to AWWA and the public water supply field, he was presented with the Diven Medal in 1935, the Goodell Prize in 1950, and the Fuller Award in 1951. He also belonged to AIChE, APHA (fellow), ASCE, British Institute of Sewage Purification (honorary member), FSIWA (vice-president), NEWWA, and a number of local water and sewage works associations, and was a past-chairman of the WSWMA Executive Committee.

Mr. Enslow possessed an inquiring and analytical mind, a quality manifested throughout his life. Those present at the meeting of the Chesapeake Section of AWWA, which he attended less than a week before his death, will recall that he participated in the technical discussions in his characteristically constructive fashion. In the course of his career, he added greatly to the professional advancement of the water industry.

Reginald M. Atwater, executive secretary of the American Public Health Assn., died Oct. 18, 1957, at the age of 65. Born at Canyon City, Colo., in 1892, he was graduated from Colorado College in 1914 and received

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an MD from Harvard in 1918. After completing his internship, he obtained a doctorate in public health from Johns Hopkins in 1921. In 1927, following a period of teaching at Hunan Yale College in China and Harvard, he became health commissioner for Cattaraugus County, N.Y., a post he held until 1935, when he was named executive secretary of APHA. He was managing editor of the *American Journal of Public Health* and chairman of the APHA Program Committee, as well as a special consultant to the US Public Health Service and a board member of the National Health Council.

Arthur C. Ford has been named to the New York City Board of Water Supply, succeeding the late Irving V. A. Huie as president. Armand D'Angelo becomes the new commissioner of the city's Dept. of Water Supply, Gas & Electricity, a post occupied by Mr. Ford since 1954. Mr. D'Angelo, an official of an International Brotherhood of Electrical Workers local, has been deputy commissioner since 1955.

The 'when' and 'where' of our favorite slogan—"All the Water You Need, When and Where You Need It!"—seem to be the major difficulties as far as the overall problem of water resources is concerned. At any rate, with our present total use estimated to be no more than 5–15 per cent of the total amount of precipitation available after transpiration and evaporation losses, it would seem that, even without going to the seas around us, we can obtain all the water we need, and then some.

The "when" problem, of course, is a matter of timing, not only of rainfall, but of water storage facilities. Thus, though an "unusually" dry year was the primary cause of the shortage in New York City in 1949–50, an important part of the "when" of it was the fact that the war had delayed completion of the Delaware River supply, which was able to carry the city through a drier period without trouble this year. Similarly, New Jersey's problem is more "when" than anything else—"when," that is, it will decide to make fuller use of the resources which are available. Actually, all through the 31 eastern states, where the average net precipitation available is estimated at 16 in., the problem is generally a "when" one, based on when communities or states or regions decide that the water available is worth the price of its development.

The "where" problem, on the other hand, is one characteristic of areas that basically do not have enough water available to support the type of economy desired. Southern California is a "where" area, in which the problem has been one of going long distances to import water and, thus, facing difficulties not only in financing the facilities required, but in obtaining rights to the water involved. On the basis of the estimate that a net of less than 1 in. of water per year is available to our western states, it is not difficult to see why the accent must be on "where."

One new "where" for the West these days has been in evaporation control, to make more of the rainfall available—and research, particularly on the use of hexadecanol in a monomolecular film to hold stored water, has been most promising. Similarly, research on various methods of desalting sea water and brackish water has been progressing, the only problem now being one of doing the job at a price the customer is willing to pay. Meanwhile, someone has finally picked a "where" even beyond our reach in suggesting a

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method of obtaining fresh water which we still consider our idea—that is, tapping icebergs. The latest version of this technique was reported recently as being "seriously considered by experts." Thus, according to John D. Isaacs of the Scripps Institute of Oceanography, "it would be possible for tugboats in Antarctic waters to guide icebergs to such water-short cities as Los Angeles." The idea is that the tugs would pick up one of the bergs that floated thousands of miles north on the Humboldt current and nudge it the rest of the way up to Los Angeles. Once the berg was in position, a watertight fence would be built around it and the ocean water would be pumped out. The berg, in melting, would form a fresh water lake that could supply the city for a full year.

With more fresh water in the polar ice caps than in all other sources combined; with Kuwait on the Persian Gulf and Curacao in the Dutch West Indies already using the sea as a source of fresh water; with eight countries backing a Dutch project to develop the Sahara and to supply farms in South Africa and Australia with water desalted electrically at costs of $1.20 per cubic meter (264.2 gal) from the sea and 39 cents per cubic meter from brackish sources; with Saudi Arabia already going ahead with plans to pipe water some 450 miles across the desert from the river Euphrates in Iraq to its 200,000-population capital city, Riyadh; and with even the Virgin Islands importing water via tugboat from Puerto Rico, who will say that it is impossible, or even impractical, for water utilities to work toward providing their customers "all the water they need, when and where they need it," provided, of cour$e . . . ?

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Poor fish is right! In the Great Lakes, the lampreys have been destroying them in such numbers that the US Fish and Wildlife Service has had to set up electrically charged lines to repel the lampreys from entering feeder streams in which they spawn or, if they have spawned, to prevent their return to the lake. At Reading, Pa., a chemical applied to remove algae scum from Carsonia Lake, used chiefly for boating and fishing, did a beautiful job on the algae, but also killed at least 10,000 fish that suffocated from lack of oxygen. And at the public water supply reservoir at Orange, N.J., there was not enough water left last month to keep a fish alive, so that men from the state fish hatchery had to remove them. Compared with a fish's, a dog's life is out of this world!

An ℞ for the water supply industry if not for the customer was filled by a New York drugstore the other day. In the language of the *New Yorker* magazine, it went:

> Friend of ours became convinced that inflation is really upon us when he stepped up to a soda fountain in a drugstore near the Coliseum the other afternoon and asked for a glass of water to wash down a pill. Along with the water, he was handed a check for ten cents. As he proffered the check and a dime to the cashier on his way out, he remarked that he thought he was paying a pretty stiff price for a glass of water. "Oh," said the cashier, "is this check just for plain water? Then we've made an error." Smiling apologetically, she reached into her cash drawer and handed him a nickel.

What price water? A nickel per tin, of course!

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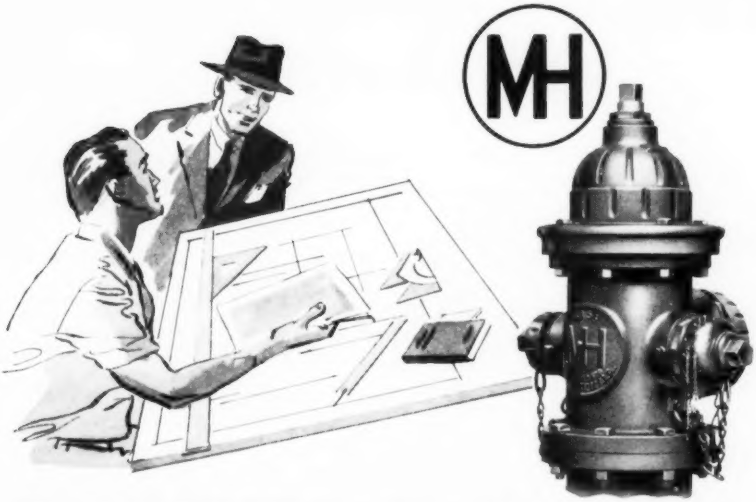
MH

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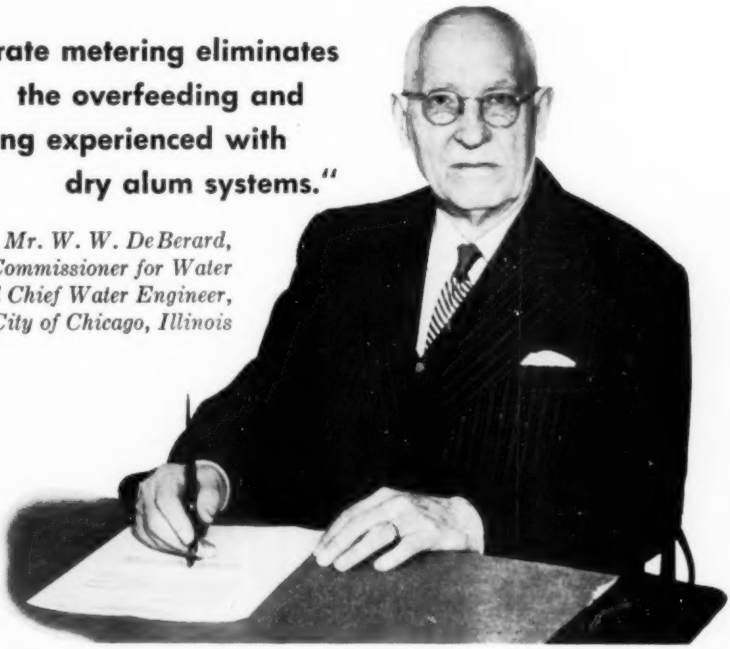

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HOH for HRH on her recent visit to Canada and the United States was said to be 99.9 per cent "pure," having been drawn from Lake Ontario and "filtered through sand, activated carbon, and paper under the strict security of the Royal Canadian Mounties." All that purity-security business sounds just a bit strange to us in the absence of any disinfectant, but we suppose that depends upon where in Lake Ontario the Mounties dipped their bucket. We were surprised, too, and, as a matter of fact, happily so, to learn from the statement that "even the royal ice cubes were made from this water," that our British cousins have at last apparently come around to the appreciation of cold drinks—perhaps even Scotch on the rocks!

A 'U-Haul-It' water distribution system for slow-paying customers has been established by the Cheyenne, Okla., water department as a means of cutting down on the number of delinquent accounts. Now service is cut off promptly on the 15th of each month for customers who have not paid, but no one is forced to go without water. All the water a customer needs is provided free of charge, but not exactly where and when he needs it. It is made available at a hydrant in the city park on a come-and-get-it basis. Not perhaps the recommended technique in public relations, the system does, nevertheless, point up quite clearly what is being paid for. The slogan, no doubt, is: "Pay up or go to haul!"

Correspondence

Water Works School

To the Editor:

You may be interested in the water works school at San Luis Obispo, Calif., which, I think, is unique in that it is conducted under the auspices of the city school system. Membership in the class, however, is by no means limited to San Luis Obispo residents. In fact, some of the enrollees travel as much as 90 miles round trip to attend.

All but two of the 32 men in the last class have had from 5 to more than 15 years of actual experience in water and sewage plant operation (two members hold master's degrees), so that the total contribution to the welfare and improvement of the class is considerable.

The course was started in October 1956 in the San Luis Obispo Adult Evening School, Dr. O. B. Paulsen, principal, largely through the efforts of John Bader, of Oceano; Robert L. Byers, of Morro Bay; and Price Thompson, Carl Young, and Sam Schultz, of San Luis Obispo. Fairly close touch is maintained with the AWWA's California Section, on whose lecture outlines the curriculum is partly based. Specialists are frequently called on to talk on legal responsibilities, flow testing, and other topics of interest.

The enthusiasm of the group indicates that the school is performing a valuable service to the citizens in general and to the water works operators of this area in particular.

CHARLES O. BLODGETT

San Luis Obispo, Calif.
Sep. 11, 1957

Mr. Blodgett, the instructor for the course, has a BS in mathematics and chemistry, a master's degree in education with a minor in mathematics from Stanford, and a master's degree in cytogenetics with a minor in botany from the University of California; he has been teaching in high school and junior college for more than 20 years.—ED.

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Condensation

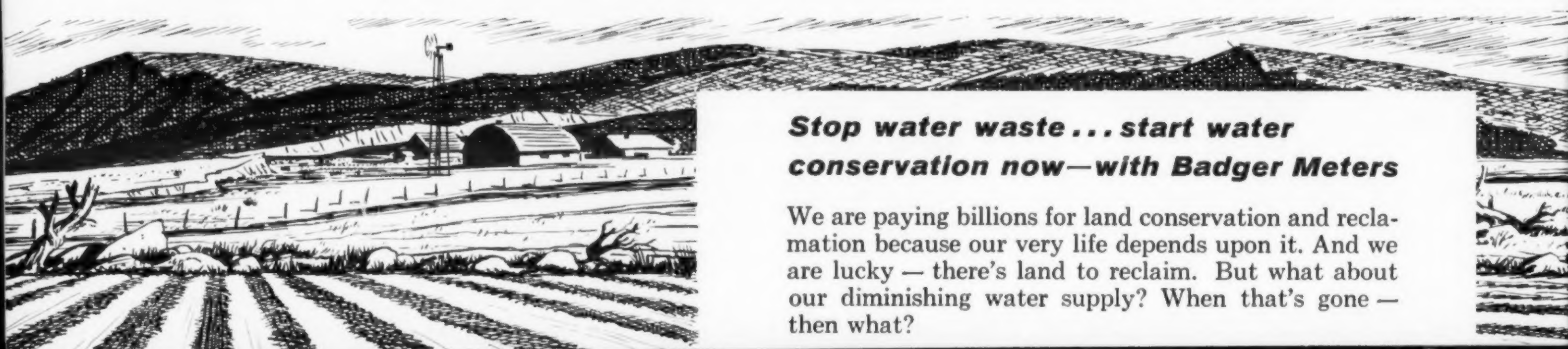
Index of Abstracts

Page numbers refer to P&R section of Journal. Letters immediately preceding page numbers refer to month of issue, using following key: Ja—January; F—February; Mr—March; Ap—April; My—May; Je—June; Jl—July; Au—August; S—September; Oc—October; N—November. All subjects and page numbers in boldface type indicate first pages of topic sections.

(*Continued on page 70 P&R*)

Soil conserved . . .

but how about our most precious possession . . . water?



Stop water waste . . . start water conservation now—with Badger Meters

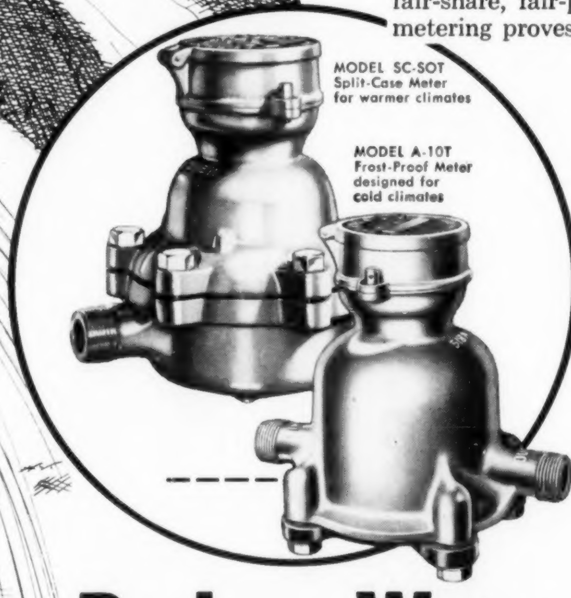
We are paying billions for land conservation and reclamation because our very life depends upon it. And we are lucky — there's land to reclaim. But what about our diminishing water supply? When that's gone — then what?

That's why the time to start water conservation is

then what?

That's why the time to start water conservation is *now*—with Badger Meters. They're the best investment you can make for your community's future. Badger Meters replace impractical and unjust flat rates with a fair-share, fair-pay program for everybody. Accurate metering proves to consumers that the best things in life are far from free. *That's* when water waste stops — conservation begins. What's more, Badger Meters put your water system on a profitable, business basis.

Choose the specific meters you need from the complete Badger Meter line of outstanding disc, turbine and compound meters — ⅝-inch through 12-inch sizes. They're precision-engineered, using the finest alloys for lasting, accurate service. Call a Badger Meter representative for facts — or write for literature *today*.



Badger Water Meters

Water is vital

Badger Meters have conserved it better for over 50 years.

BADGER METER MFG. CO. • 2371 North 30th Street
Milwaukee 45, Wisconsin • OFFICES IN PRINCIPAL CITIES

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Authors of Abstracted Articles

Page numbers refer to P&R section of Journal. Letters in italics immediately preceding page numbers refer to month of issue, in accordance with following key: Ja—January; F—February; Mr—March; Ap—April; My—May; Je—June; Jl—July; Au—August; S—September; Oc—October; N—November.

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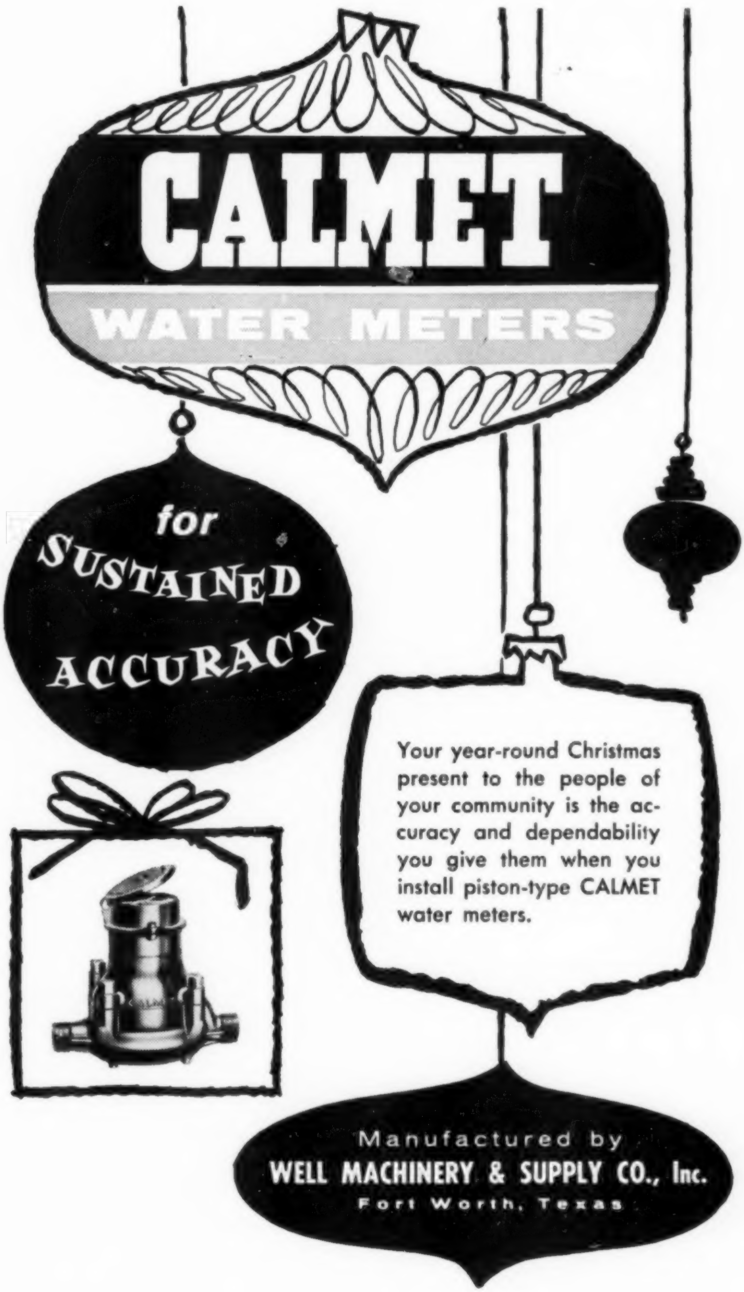
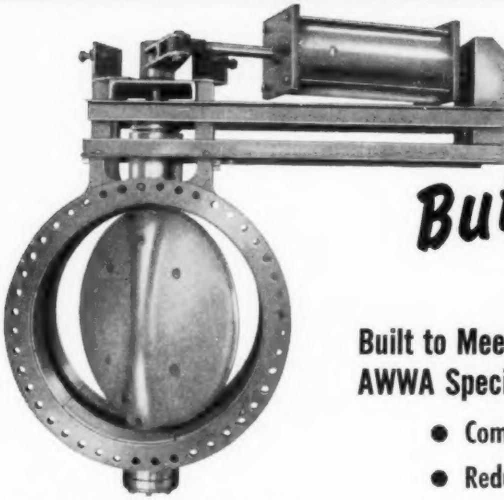
(*Continued on page 84 P&R*)


CALMET
WATER METERS
for
SUSTAINED
ACCURACY
Your year-round Christmas present to the people of your community is the accuracy and dependability you give them when you install piston-type CALMET water meters.
Manufactured by
WELL MACHINERY & SUPPLY CO., Inc.
Fort Worth, Texas

(*Continued from page 82 P&R*)

(*Continued on page 88 P&R*)

SAVE SPACE – SAVE COSTS



AWWA 48", 125# valve for drop-tight shut-off at 100 psi. Renewable rubber seat; hydraulic cylinder operator.

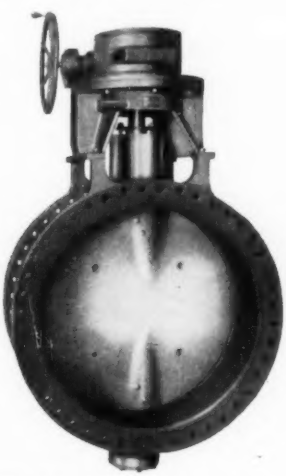
with

W. S. ROCKWELL

Butterfly Valves

Built to Meet All AWWA Specifications

- Compact—Lighter Weight
- Reduced Installation Space
- Lowest Installed Cost
- Efficient Reliable Operation
- Drop-Tight Shutoff
- Minimum Restriction to Flow
- Minimum Pressure Drop
- Non-Clogging
- Better Control—Manual or Automatic
- Less Maintenance



AWWA 60", 50# valve for drop-tight shut-off at 35 psi water pressure. Cast iron body with spool type rubber liner; with worm gear and handwheel operator.

W. S. Rockwell Butterfly Valves are made in all standard sizes of cast iron, cast steel, stainless steel, bronze or other alloys; natural or synthetic gum rubber seat with clamping segments, or spool type rubber liner extending over flange faces. Operators—manual: AWWA nut, handwheel, chain wheel or other types; automatic: electric motor or cylinder. Write for Bulletin 574.

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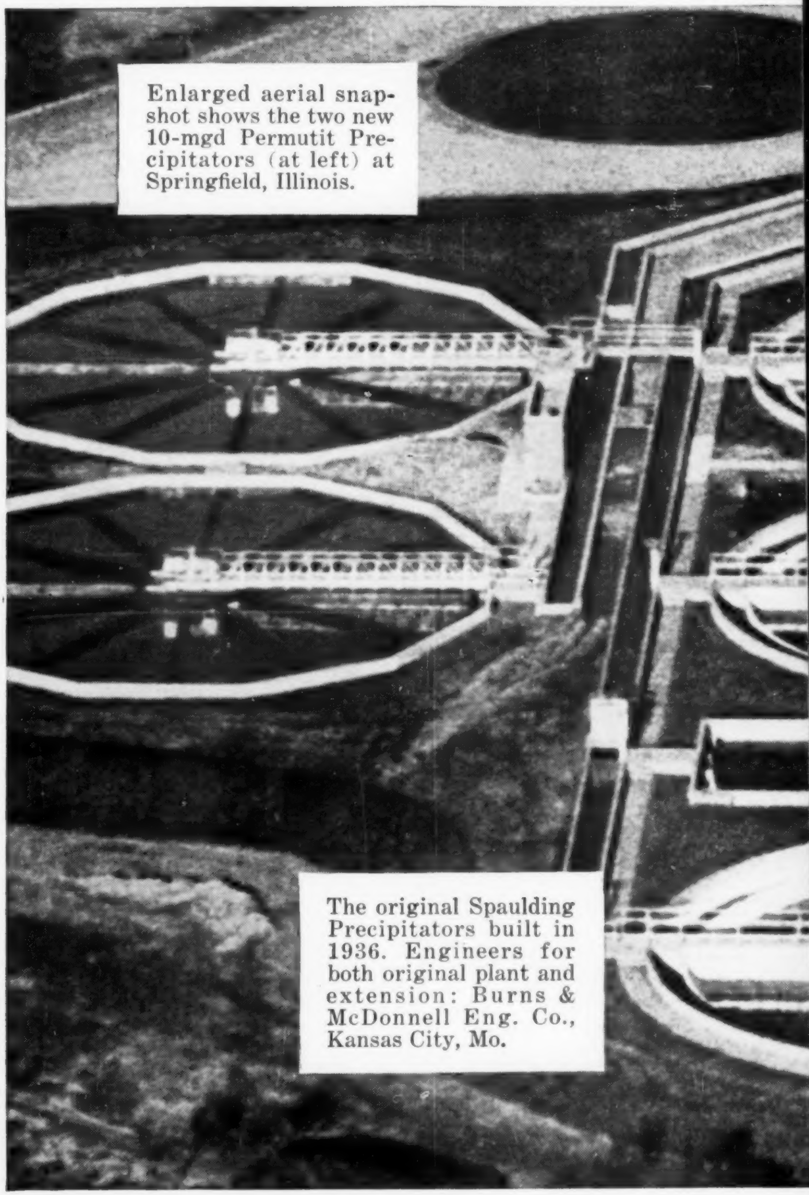

Enlarged aerial snapshot shows the two new 10-mgd Permutit Precipitators (at left) at Springfield, Illinois.

The original Spaulding Precipitators built in 1936. Engineers for both original plant and extension: Burns & McDonnell Eng. Co., Kansas City, Mo.

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MEMBERSHIP METER
TOTAL
12,217
NOV 1 1957
AMERICAN WATER WORKS ASSOCIATION

NEW MEMBERS

Applications received Oct. 1–31, 1957

Adams, John C., Jr., Chief Engr., Coffin & Richardson, Inc., 68 Devonshire St., Boston 9, Mass. (Oct. '57) *M*

Allmon, Larry Elmer, Utilities Supt., DX-Sunray Oil Co., Box 831, Duncan, Okla. (Oct. '57) *P*

Armstrong, George, Jr., Supt. of Water & Sewage Treatment, 223 Cherry St., St. Mary's, Ohio (Oct. '57) *P*

Becker, Jack, Sales Engr., The East Asiatic Co., 465 California St., Fremont, Calif. (Oct. '57) *D*

Bernharth, George, Design Engr., Parsons, Brinckerhoff, Hail & MacDonald, 51 Broadway, New York 6, N. Y. (Oct. '57) *RPD*

Beyer, Arnold J., Chief Engr., Gary Steel Works, US Steel Corp., 1 N. Broadway, Gary, Ind. (Oct. '57) *PD*

Bloomington Water & Light Dept., M. L. Burgin, Director of Utilities, Box 674, Bloomington, Ill. (Munic. Sv. Sub. Oct. '57) *MRPD*

Bonner, Tom F., Supt. of Water & Sewer, Box 465, Fort Sumner, N.M. (Oct. '57) *MD*

Bottelsen, Walter Henry, Gen. Mgr., Cachuma Operation & Maint. Bd., 3301 Laurel Canyon Rd., Santa Barbara, Calif. (Oct. '57) *M*

Bremkamp, James K., Field Engr., Water Bond Issue Program, Munic. Bldg., Oklahoma City, Okla. (Oct. '57) *RD*

Bull, Thomas, West Coast Mgr., Cuno Eng. Corp., Box 271, Burlingame, Calif. (Oct. '57) *P*

Burgin, M. L.; *see* Bloomington (Ill.) Water & Light Dept.

Burzell, Linden R., Mgr., 402 Plymouth Dr., Vista, Calif. (Oct. '57) *M*

Butler, Jack D., Sales Engr., Lock Joint Pipe Co., Box 269, East Orange, N.J. (Oct. '57) *D*

Campbell, James Roland, Sales Engr., 4637 N. Hartford, Tulsa, Okla. (Oct. '57) *D*

Carhart, Kenneth J., Chief, Bureau of Examination & Licensing, State Dept. of Health, State House, Trenton 25, N.J. (Oct. '57) *MRPD*

Casey, Charles M.; *see* Nichols Hills (Okla.)

Chafetz, Arthur B., Cons. Engr., 838 S. Canyon, Carlsbad, N. Mex. (Oct. '57) *MRPD*

Chase, Thomas B., Foreman, Meter Repair Shop, 301 Bryant St., N.W., Washington, D. C. (Oct. '57) *D*

Cleland, Wilson M., Chief Operator, 310 S. 2nd St., St. Clair, Mich. (Oct. '57) *P*

Cohen, Seymour Philip, Jr. Civ. Engr., Dept. of Water Resources, 1100 S. Grand Ave., Los Angeles, Calif. (Oct. '57) *R*

Colangelo, Anthony J., Sales Engr., Turbine Equipment Co., 63 Vesey St., New York 7, N.Y. (Oct. '57) *RD*

Cowles, Robert, Co-Partner, C&M Dredging, 4215 Cassopolis St., Elkhart, Ind. (Oct. '57) *PD*

Crawley, Evan, Mayor, City Hall, Greencastle, Ind. (Oct. '57)

Crom, James A., Engr., Stevens & Thompson, Box 508, Portland 7, Ore. (Oct. '57) *RPD*

Cross, C. L., Foreman, Alexandria Water Dept., Rte. 1, Boyce, La. (Oct. '57)

Curtis, William A., Office Engr., Boyle Eng., 3913 Ohio St., San Diego 4, Calif. (Oct. '57) *D*

Dagley, Leslie L., Vice-Mayor, 511 E. Valley Blvd., El Monte, Calif. (Oct. '57) *MP*

(*Continued on page 96 P&R*)

(Continued from page 94 P&R)

Danielsen, Glen Earle, Director of Public Works, 7681—9th St., Buena Park, Calif. (Oct. '57) *M*

Davis, Herman Dempsey, Sales Engr., Link-Belt Co., 5938 Linsdale Ave., Detroit 4, Mich. (Oct. '57) *P*

Deal, Robert Louis, Supt., Power & Fuel Div., US Steel Corp., Gary Steel Works, Gary, Ind. (Oct. '57) *D*

Dellisanti, Adam J., Supervisor of Distr., Water Dept., 1106—1st St., Lorain, Ohio (Oct. '57) *D*

Dembitz, Adolph Edward, Chief Utilities Engr., Singmaster & Breyer, Inc., 420 Lexington Ave., New York 17, N.Y. (Oct. '57) *RD*

Dougherty, Donald F., Dist. Engr., Branch of Surface Water, Water Resources Div., US Geological Survey, Box 967, Trenton 6, N.J. (Oct. '57)

Drew, Howard R., Sr. Engr., Texas Electric Service Co., Box 970, Fort Worth, Tex. (Oct. '57) *R*

Dunlap, Lester Bennett, Engr., Brown & Caldwell, 66 Mint St., San Francisco 3, Calif. (Oct. '57) *R*

Dymock, Thomas, Project Engr., James F. MacLaren Assocs., 321 Bloor St., E., Toronto, Ont. (Oct. '57) *MRPD*

Fitch, Robert J., Sales Engr., Traverse City Iron Works, Traverse City, Mich. (Oct. '57) *PD*

Fox, Joseph M., Asst. Supervisor, Dept. of Public Works, Paterson, N.J. (Oct. '57) *D*

Friedgen, Robert D., Civ. Engr., Helix Irrigation Dist., 743 Katherine Place, El Cajon, Calif. (Oct. '55)

Galeano, Sergio F. Fortun, Civ. Engr., Ingenieria Vame S.A., Rancho Boyeros 774, Havana, Cuba (Oct. '57) *P*

Gibbon, R. G., Sales Repr., Worthington-Gamon Meter Div., 2113 Ong St., Amarillo, Tex. (Oct. '57)

Gilchrist, W. A.; *see* Glendale (Ariz.)

Glendale, City of, W. A. Gilchrist, City Mgr., 38 N. 1st Ave., Glendale, Ariz. (Corp. M. Oct. '57) *MPD*

Green, Kenneth, Partner, Green Eng. Co., 1926 University Ave., Middleton, Wis. (Oct. '57)

Greenwich, Village of, Water Com., Harold C. Kipp, Water Supt., 79 Main St., Greenwich, N.Y. (Munic. Sv. Sub. Oct. '57)

Gronlund, Carl J., Mgr., County Waterworks Dists., 5082 N. Palm Ave., Fresno, Calif. (Oct. '57) *MD*

Grundy Center, City of, City Clerk, City Hall, Grundy Center, Iowa (Corp. M. Oct. '57) *MRPD*

Haberman, John M., Tech. Supervisor, Floyd G. Browne & Assocs., Marion, Ohio (Oct. '57) *MP*

Hamilton, James H., Resident Engr., Wiederman & Singleton, 760 W. Peachtree St., Atlanta, Ga. (Oct. '57) *PD*

Hamilton, Paul B., Water Works Supt., Water Works, Town Hall, Centerville, Ind. (Oct. '57) *MRPD*

Haneman, A., Jr., Supt., Water & Sewer Dept., Box 60, Abilene, Tex. (Oct. '57)

Haney, Ben J., Jr., Mech. Engr., Sewerage & Water Bd., New Orleans, La. (Oct. '57) *MD*

Hanger, Dave, Supt., Water Dept., Morocco, Ind. (Oct. '57)

Hansen, Ronald G., Asst. San. Engr., Water Quality Sec., State Dept. of Water Resources, 1100 S. Grand Ave., Los Angeles, Calif. (Oct. '57) *R*

Harris, R. F., Supt. of Distr., Water Dept., Box 449, Waco, Tex. (Oct. '57) *MD*

Harrold, Homer, Water Supt., Bd. of Trustees of Public Affairs, 579 Pittsburg St., Columbiana, Ohio (Oct. '57)

Hedrick, O. W.: *see* Knightdale (N.C.)

Henry, Marvin D., Asst. Water Supt., Water Dept., 1227 S. Riverside, Rialto, Calif. (Oct. '57) *MRPD*

(Continued on page 98 P&R)

Part of the skyline at FARGO, NORTH DAKOTA

(Continued from page 96 P&R)

Herkless, Heber G., Works Mgr., Water & Light Plant, 19 N. Franklin St., Knightstown, Ind. (Oct. '57) *MD*

Hill, Harlan F., Supt., North Coast County Water Dist., Box 35, Sharp Park, Calif. (Oct. '57) *D*

Holden, Clarence R., Supt. of Plants, Water & Sewage Dept., Tulsa, Okla. (Oct. '57)

Holladay, Joe B., Asst. Water Supt., 118 N. Broadway, Weatherford, Okla. (Oct. '57) *PD*

Holtzclaw, Leon V., Asst. Supt., Water Dept., 3449 Central Ave., Port Arthur, Tex. (Oct. '57)

Hooper, Brian G., Dorr-Oliver-Long Ltd., 1819 Yonge St., Toronto 7, Ont. (Oct. '57)

Hori, Rijo, Civ. Engr., Bd. of Water Supply, Box 3410, Honolulu, T.H. (Oct. '57) *MR*

Hothan, Arwin W., San. Engr., Consoer, Townsend & Assoc., 360 E. Grand Ave., Chicago 11, Ill. (Oct. '57) *RPD*

Hovey, David H., Partner, Hovey-Cole & Assocs., 3734 Florida St., Baton Rouge, La. (Oct. '57) *PD*

Hutson, E. R., Supt., Water Dept., Box 974, Brownfield, Tex. (Oct. '57)

Hyre, Luther P., Branch Mgr., Chem. Dept., McKesson & Robbins, Inc., 216 Elm St., Des Moines, Iowa (Oct. '57) *P*

Imrie, George, Director of Public Works, Box 588, Reedley, Calif. (Oct. '57) *M*

Jackson, Robert F., Chief, Flood Control Sec., State Flood Control & Water Resources Com., 1330 W. Michigan St., Indianapolis 7, Ind. (Oct. '57) *R*

Jidy, Raul, Elec. Engr., Manzana de Gomez 314, Havana, Cuba (Oct. '57) *M*

Johnston, Floyd L., Supt. of Utilities, Box 253, Refugio, Tex. (Oct. '57)

Katz, Albert L., Jr., Sales Repr., Goodall Rubber Co., 2050 N. Hawthorne Ave., Melrose Park, Ill. (Oct. '57) *P*

Kelley, W. R., Water Plant Supt., Rte. 2, Foss, Okla. (Oct. '57)

Killam, Robert B., Temporary Town Engr., Yarmouth, N.S. (Oct. '57)

Kipp, Harold C.; *see* Greenwich (N.Y.) Water Com.

Klamser, Robert P., City Engr., Box 151, Raymond, Wash. (Oct. '57) *D*

Kleinoeder, Robert E., City Engr., City Hall, Elyria, Ohio (Oct. '57) *D*

Knapp, Earle, Supt. of Public Works, 1820 Inverness, Pontiac, Mich. (Oct. '57) *RD*

Knightdale, Town of, O. W. Hedrick, Town Clerk, Knightdale, N.C. (Munic. Sv. Sub. Oct. '57) *MD*

Knisley, Marshall C., Supt. of Public Works, 7681—9th St., Buena Park, Calif. (Oct. '57) *D*

Kruse, Marvin Otto, Cons. Engr., Kruse Eng. Service, Spencer, Iowa (Oct. '57) *RPD*

La Junta Munic. Utilities, Tom Russell, City Mgr., 4th & Santa Fe, La Junta, Colo. (Corp. M. Apr. '57)

LeFevers, J. H., Acting Supt., Water Dept., Box 449, Waco, Tex. (Oct. '57) *M*

Lewis, Howard C., Mgr., Pump Dept., A. Y. McDonald Mfg. Co., 629 S.W. 9th, Des Moines, Iowa (Oct. '57) *RD*

Lingan, James B., Supt. of Mech. & Elec. Maint., Bureau of Water Supply, 3001 Druid Park Dr., Baltimore 15, Md. (Oct. '57)

Luckett, D. C., Foreman, Water Dept., 1806 Elliott, Alexandria, La. (Oct. '57)

Lufkin, City of, Harold Schmitzer, City Mgr., City Hall, Lufkin, Tex. (Munic. Sv. Sub. Oct. '57) *RD*

Mabin, William; *see* Scottsbluff (Neb.) Water Dept.

Macri, Nicholas D., Asst. Water Works Supt., Village Hall, Scarsdale, N.Y. (Oct. '57) *MPD*

Magnafichi, Rudolph F., Supt., Inland Lakes Sewer & Water Co., 661 Lake St., Grayslake, Ill. (Oct. '57) *MP*

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Maurice, Bertram C., Chief, Maint. Sec., Dalecarlia Filter Plant, 4900 MacArthur Blvd., N.W., Washington 16, D.C. (Oct. '57) *M*

McCain, H. C., Sales Engr., Rockwell Mfg. Co., Box 2126, Houston, Tex. (Oct. '57) *D*

McClure, Warren A., Gen. Mgr., North Coast County Water Dist., Box 35, Sharp Park, Calif. (Oct. '57) *MD*

McClure, Warren A.; *see* North Coast County (Calif.) Water Dist.

McCoy, Lewis J., San. Eng. Graduate, Northwestern Univ., Evanston, Ill. (Jr. M. Oct. '57) *MP*

McFadden, Robert Burton, Asst. Water Supt., Water Dept., Bentonville, Ark. (Oct. '57) *MRPD*

McPherson, Arthur G., Regional Sales Repr., Adams Pipe Repair Products, Box 36, Scottsburg, Ind. (Oct. '57) *M*

Meharry, John F., Salesman, Hersey Mfg. Co., Box 31, Dedham, Mass. (Oct. '57) *D*

Miller, Fred W., Asst. Supt., Water & Sewer System, Public Service Bd., El Paso, Tex. (Oct. '57)

Milne, Frank, Sales Repr., Hersey Mfg. Co., Box 643, Rochester 2, N.Y. (Oct. '57) *D*

Moore, Detmer H., Supt. of Munic. Utilities, State Center, Iowa (Oct. '57)

Moses, H. R.; *see* Waxahachie (Tex.)

Muench, Ray A., Jr., Admin. Asst., Public Works Com., Fayetteville, N.C. (Oct. '57) *M*

Neumeyer, Charles F., Supervisor, Water Plant, L-O-F Glass Fibers Co., Waterville, Ohio (Oct. '57) *MP*

Nichols Hills, Town of, Charles M. Casey, Foreman, Water Dept., 6407 Avondale Dr., Oklahoma City 14, Okla. (Corp. M. Oct. '57) *M*

Noecker, Max, Prin. Engr., State Flood Control & Water Resources Com., 1330 W. Michigan, Indianapolis, Ind. (Oct. '57) *R*

North Coast County Water Dist., Warren A. McClure, Gen. Mgr., Box 35, Sharp Park, Calif. (Corp. M. Oct. '57) *MRD*

O'Shea, Daniel G., Project Engr., Weyerhauser Timber Co., Box 1645, Tacoma 1, Wash. (Oct. '57) *RPD*

Patera, Edward L., Cons. Engr., 623 Royal Union Bldg., Des Moines, Iowa (Oct. '57)

Pedersen, Carl, Jr., Sales Engr., Purser & London, Inc., Box 4156, Charlotte, N.C. (Oct. '57) *D*

Permenter, Art, Sales Engr., Standard Sand & Silica Co., Box 35, Davenport, Fla. (Oct. '57) *P*

Peterson, Thoburn F., Asst. City Engr., Grand Forks, N.D. (Oct. '57) *D*

Piehl, Robert A., Jr., Engr., De-Laval Steam Turbine Co., 1237 Texas National Bank Bldg., Houston 1, Tex. (Oct. '57) *RD*

Quate, Boyd E., Vice-Pres., Weather Engrs., Inc., 6151 Freeport Blvd., Sacramento, Calif. (Oct. '57) *R*

Reimers, Richard C., Contracting Engr., Pittsburgh-Des Moines Steel Co., Neville Island, Pittsburgh 9, Pa. (Oct. '57) *D*

Rogers, Robert R., Sales Repr., Goodall Rubber Co., 2050 N. Hawthorne Ave., Melrose Park, Ill. (Oct. '57) *P*

Ronsen, Gustav A., Plant Engr., Goodall Rubber Co., 2050 N. Hawthorne Ave., Melrose Park, Ill. (Oct. '57) *PD*

Russell, Tom; *see* La Junta (Colo.) Munic. Utilities

St. Louis, City of, Donald P. Ziemke, City Mgr., 108 W. Saginaw, St. Louis, Mich. (Munic. Sv. Sub. Oct. '57) *M*

Schmitzer, Harold; *see* Lufkin (Tex.)

Scottsbluff, City of, Water Dept., William Mabin, Supt., Scottsbluff, Neb. (Corp. M. Oct. '57) *MRP*

Waxahachie, City of, H. R. Moses, Water Supt., Waxahachie, Tex. (Corp. M. Oct. '57)

Ziemke, Donald P.; *see* St. Louis (Mich.)

engineering

New ideas–for new products and improvements on current products–are carefully analyzed and any with merit are passed on to trained project engineers for development. Approved designs are produced in the Mueller pattern shops by skilled craftsmen, and tested exhaustively–insuring performance in your equipment of tomorrow!

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solving your problems of tomorrow–today!

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research

Metals, and other materials used in the manufacture of Mueller products, are subjected to rigorous tests and checks by laboratory technicians. This constant search is for improvements to provide longer life and safer operating methods in the products you are using today *and* tomorrow.

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Production methods are under study at all times to gain greater accuracy and quality. New machine tools and equipment are constantly being added to Mueller plant facilities to add more precision to Mueller products. Dependability—today and in the future—is assured!

COMING YOUR WAY...

1957 was a year of spectacular engineering accomplishment at Mueller Co. New engineering facilities were dedicated and from the boards of an expanded engineering staff came new and improved products. These products will soon be announced, and will be ready for you in '58!

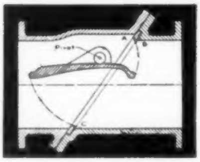
Section Meetings

Kentucky-Tennessee Section: The 29th annual meeting of the Kentucky-Tennessee Section was held Sep. 23–25 jointly with the Kentucky-Tennessee Industrial Wastes & Sewage Works Assn. The total registration was 317, which tied the record set in 1956. There was a large turnout of ladies—74 registered, compared with the previous high of about 50. Joint sessions of the two groups were held on Monday, Sep. 23, with separate sessions on Tuesday and Wednesday.

The address of welcome was given by Henry Gerber, president of the Louisville Water Co., and Robert L. Lawrence, director of the Nashville Water Dept., gave the response. Excellent technical papers, panel discussions, and interesting movies were presented during the meeting. [A list of the papers and their authors appears on p. 1609 of this issue.]

The Louisville Water Co. was host at a dinner on Monday evening, and the Annual Banquet and Dance was held Tuesday evening. WSWMA held a cocktail party prior to the banquet. The follow-

(Continued on page 104 P&R)



Section Meetings

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ing awards were announced during the banquet: Fuller Award nomination to Charles H. Bagwell, Knoxville, Tenn.; Safety Award of Merit to Union City (Tenn.), Danville (Ky.), Corbin (Ky.), Hallsdale-Powell Utility Dist. (Tenn.), Whitehaven Utility Dist. (Tenn.), Hazard (Ky.), and Cumberland (Ky.); Safety Award of Honor to Memphis and Knoxville.

Officers selected to serve during the coming year are: chairman—Joe W. Lovell, Murfreesboro, Tenn.; vice-chairman—Henry M. Gerber, Louisville, Ky.; secretary-treasurer—J. Wiley Finney Jr., Lexington, Ky.; director—Elmer Smith, Owensboro, Ky.; trustee (Kentucky)—Jack D. Boxley, Hopkinsville; trustee (Tennessee)—Robert L. Lawrence Jr., Nashville; past-chairman—Robert A. Fischer, Covington, Ky.

J. WILEY FINNEY JR.
Secretary-Treasurer

Employment Information

Classified ads will be accepted only for "Positions Available" or "Position Wanted." Rate: $1.50 per line (minimum $5.00), payable before publication. Deadline for ad copy: first of month prior to month of publication desired. To place ad, obtain "Classified Ad Authorization Form" from: Classified Ad Dept., Journal American Water Works Assn., 2 Park Ave., New York 16, N.Y.

Positions Wanted

HYDRAULIC ENGINEER: 14 years experience in pipelines, pumping, water resources. **Desires to** locate in Washington, D.C., as representative of water supply equipment manufacturer. Box 111, Journal American Water Works Assn., 2 Park Ave., New York 16, N.Y.

Index of Advertisers' Products

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Allis-Chalmers Mfg. Co.
United States Pipe & Foundry Co.

Contractors, Water Supply:
Layne & Bowler, Inc.

Controllers, Liquid Level, Rate of Flow:
Builders-Providence, Inc. (Div., B-I-F Industries, Inc.)
Foxboro Co.
General Filter Co.
Infilco Inc.
Simplex Valve & Meter Co.
Sparling Meter Co.

Copper Sheets:
American Brass Co.

Copper Sulfate:
General Chemical Div.
Tennessee Corp.

Corrosion Control:
Calgon Co.
Philadelphia Quartz Co.

Couplings, Flexible:
DeLaval Steam Turbine Co.
Dresser Mfg. Div.

Diaphragms, Pump:
Dorr-Oliver Inc.

Engines, Hydraulic:
Ross Valve Mfg. Co.

Engineers and Chemists:
(See Professional Services)

Feedwater Treatment:
Allis-Chalmers Mfg. Co.
Calgon Co.
Cochrane Corp.
Graver Water Conditioning Co.
Hungerford & Terry, Inc.
Infilco Inc.
Permutit Co.
Proportioneers, Inc. (Div., B-I-F Industries, Inc.)

Ferric Sulfate:
Tennessee Corp.

Filter Materials:
Anthracite Equipment Corp.
Carborundum Co.
Dicalite Div.
General Filter Co.
Infilco Inc.
Johns-Manville Corp.
Northern Gravel Co.
Permutit Co.

Filters, incl. Feedwater:
Cochrane Corp.
Dorr-Oliver Inc.
Etablissements Degremont
Graver Water Conditioning Co.
Infilco Inc.
Permutit Co.
Proportioneers, Inc. (Div., B-I-F Industries, Inc.)
Roberts Filter Mfg. Co.
Ross Valve Mfg. Co.

Filtration Plant Equipment:
Builders-Providence, Inc. (Div., B-I-F Industries, Inc.)
Chain Belt Co.
Cochrane Corp.
Etablissements Degremont
Filtration Equipment Corp.
General Filter Co.
Graver Water Conditioning Co.
Hungerford & Terry, Inc.
Infilco Inc.
F. B. Leopold Co.
Omega Machine Co. (Div., B-I-F Industries, Inc.)
Permutit Co.
Roberts Filter Mfg. Co.
Simplex Valve & Meter Co.
Wallace & Tiernan Inc.

Fittings, Copper Pipe:
Dresser Mfg. Div.
M. Greenberg's Sons
Hays Mfg. Co.
Mueller Co.

Fittings, Tees, Ells, etc.:
American Cast Iron Pipe Co.
Cast Iron Pipe Research Assn.
James B. Clow & Sons
Crane Co.
Dresser Mfg. Div.
M & H Valve & Fittings Co.
Trinity Valley Iron & Steel Co.
United States Pipe & Foundry Co.
R. D. Wood Co.

Flocculating Equipment:
Chain Belt Co.
Cochrane Corp.
Dorr-Oliver Inc.
General Filter Co.
Graver Water Conditioning Co.
Infilco Inc.
F. B. Leopold Co.
Permutit Co.

Fluoride Chemicals:
American Agricultural Chemical Co.
Tennessee Corp.

Fluoride Feeders:
Milton Roy Co.
Omega Machine Co. (Div., B-I-F Industries, Inc.)
Proportioneers, Inc. (Div., B-I-F Industries, Inc.)
Wallace & Tiernan Co., Inc.

Furnaces:
Jos. G. Pollard Co., Inc.

Gages, Liquid Level:
Builders-Providence, Inc. (Div., B-I-F Industries, Inc.)
Burgess-Manning Co., Penn Instruments Div.
Infilco Inc.
Simplex Valve & Meter Co.
Sparling Meter Co.
Wallace & Tiernan Inc.

Gages, Loss of Head, Pressure of Vacuum, Rate of Flow, Sand Expansion:
Builders-Providence, Inc. (Div., B-I-F Industries, Inc.)
Burgess-Manning Co., Penn Instruments Div.
Foxboro Co.
Infilco Inc.
Jos. G. Pollard Co., Inc.
Simplex Valve & Meter Co.
Wallace & Tiernan Inc.

Gasholders:
Bethlehem Steel Co.
Chicago Bridge & Iron Co.
Graver Tank & Mfg. Co.
Hammond Iron Works
Pittsburgh-Des Moines Steel Co.

Gaskets, Rubber Packing:
James B. Clow & Sons
Johns-Manville Corp.

Gates, Shear and Sluice:
Armco Drainage & Metal Products, Inc.
Chapman Valve Mfg. Co.
James B. Clow & Sons
Mueller Co.
R. D. Wood Co.

Gears, Speed Reducing:
DeLaval Steam Turbine Co.
Worthington Corp.

Glass Standards—Colorimetric Analysis Equipment:
Klett Mfg. Co.
Wallace & Tiernan Inc.

Goosenecks (with or without Corporation Stops):
James B. Clow & Sons
Hays Mfg. Co.
Mueller Co.

Hydrants:
James B. Clow & Sons
Darling Valve & Mfg. Co.
M. Greenberg's Sons
Kennedy Valve Mfg. Co.
Ludlow Valve Mfg. Co., Inc.
M & H Valve & Fittings Co.
Mueller Co.
A. P. Smith Mfg. Co.
Rensselaer Valve Co.
R. D. Wood Co.

Hydrogen Ion Equipment:
Wallace & Tiernan Inc.

Hypochlorite; see Calcium Hypochlorite; Sodium Hypochlorite

Ion Exchange Materials:
Allis-Chalmers Mfg. Co.
Cochrane Corp.
General Filter Co.
Graver Water Conditioning Co.
Hungerford & Terry, Inc.
Infilco Inc.
Permutit Co.
Roberts Filter Mfg. Co.

Iron, Pig:
Woodward Iron Co.

Iron Removal Plants:
American Well Works
Chain Belt Co.
Cochrane Corp.
General Filter Co.
Graver Water Conditioning Co.
Hungerford & Terry, Inc.
Infilco Inc.
Permutit Co.
Roberts Filter Mfg. Co.
Walker Process Equipment, Inc.

Jointing Materials:
Hydraulic Development Corp.
Johns-Manville Corp.
Keasbey & Mattison Co.
Leadite Co., Inc.

Joints, Mechanical, Pipe:
American Cast Iron Pipe Co.
Cast Iron Pipe Research Assn.
James B. Clow & Sons
Dresser Mfg. Div.
Trinity Valley Iron & Steel Co.
United States Pipe & Foundry Co.
R. D. Wood Co.

Leak Detectors:
Jos. G. Pollard Co., Inc.

Lime Slakers and Feeders:
Dorr-Oliver Inc.
General Filter Co.
Infilco Inc.
Omega Machine Co. (Div., B-I-F Industries, Inc.)
Permutit Co.
Wallace & Tiernan Inc.

Magnetic Dipping Needles:
W. S. Darley & Co.

Meter Boxes:
Ford Meter Box Co.
Pittsburgh Equitable Meter Div.

Meter Couplings and Yokes:
Badger Meter Mfg. Co.
Dresser Mfg. Div.

Ford Meter Box Co.
Hays Mfg. Co.
Hersey Mfg. Co.
Mueller Co.
Neptune Meter Co.
Pittsburgh Equitable Meter Div.
Worthington-Gamon Meter Co.

Meter Reading and Record Books:
Badger Meter Mfg. Co.

Meter Testers:
Badger Meter Mfg. Co.
Ford Meter Box Co.
Hersey Mfg. Co.
Neptune Meter Co.
Pittsburgh Equitable Meter Div.

Meters, Domestic:
Badger Meter Mfg. Co.
Buffalo Meter Co.
Hersey Mfg. Co.
Neptune Meter Co.
Pittsburgh Equitable Meter Div.
Well Machinery & Supply Co.
Worthington-Gamon Meter Co.

Meters, Filtration Plant, Pumping Station, Transmission Line:
Builders-Providence, Inc. (Div., B-I-F Industries, Inc.)
Burgess-Manning Co., Penn Instruments Div.
Foster Eng. Co.
Infilco Inc.
Simplex Valve & Meter Co.
Sparling Meter Co.

Meters, Industrial, Commercial:
Badger Meter Mfg. Co.
Buffalo Meter Co.
Builders-Providence, Inc. (Div., B-I-F Industries, Inc.)
Burgess-Manning Co., Penn Instruments Div.
Hersey Mfg. Co.
Neptune Meter Co.
Pittsburgh Equitable Meter Div.
Simplex Valve & Meter Co.
Sparling Meter Co.
Well Machinery & Supply Co.
Worthington-Gamon Meter Co.

Meter Repair Parts
Meter Specialty Co.

Mixing Equipment:
Chain Belt Co.
General Filter Co.
Infilco Inc.
F. B. Leopold Co.

Paints:
Barrett Div.
Inertol Co., Inc.
Koppers Co., Inc.

Pipe, Asbestos-Cement:
Johns-Manville Corp.
Keasbey & Mattison Co.

Pipe, Brass:
American Brass Co.

Pipe, Cast Iron (and Fittings):
Alabama Pipe Co.
American Cast Iron Pipe Co.
Cast Iron Pipe Research Assn.
James B. Clow & Sons
Trinity Valley Iron & Steel Co.
United States Pipe & Foundry Co.
R. D. Wood Co.

Pipe, Cement Lined:
American Cast Iron Pipe Co.
Cast Iron Pipe Research Assn.
James B. Clow & Sons
United States Pipe & Foundry Co.
R. D. Wood Co.

Pipe, Concrete:
American Concrete Pressure Pipe Assn.
American Pipe & Construction Co.
Lock Joint Pipe Co.

Pipe, Copper:
American Brass Co.

Pipe, Steel:
Armco Drainage & Metal Products, Inc.
Bethlehem Steel Co.

Pipe Cleaning Services:
National Water Main Cleaning Co.

Pipe Cleaning Tools and Equipment:
Flexible Inc.

Pipe Coatings and Linings:
American Cast Iron Pipe Co.
Barrett Div.
Cast Iron Pipe Research Assn.
Centriline Corp.
Inertol Co., Inc.
Koppers Co., Inc.
Reilly Tar & Chemical Corp.

Pipe Cutters:
James B. Clow & Sons
Ellis & Ford Mfg. Co.
Jos. G. Pollard Co., Inc.
Reed Mfg. Co.
A. P. Smith Mfg. Co.

Pipe Jointing Materials; see Jointing Materials

Pipe Locators:
W. S. Darley & Co.
Jos. G. Pollard Co., Inc.

Pipe Vises:
Reed Mfg. Co.

Plugs, Removable:
James B. Clow & Sons
Jos. G. Pollard Co., Inc.
A. P. Smith Mfg. Co.

Potassium Permanganate:
Carus Chemical Co.

Pressure Regulators:
Allis-Chalmers Mfg. Co.
Foster Eng. Co.
Golden-Anderson Valve Specialty Co.
Mueller Co.
Ross Valve Mfg. Co.

Pumps, Boiler Feed:
Allis-Chalmers Mfg. Co.
DeLaval Steam Turbine Co.
Layne & Bowler Pump Co.
Worthington Corp.

Pumps, Centrifugal:
Allis-Chalmers Mfg. Co.
American Well Works
DeLaval Steam Turbine Co.
C. H. Wheeler Mfg. Co.
Worthington Corp.

Pumps, Chemical Feed:
Infilco Inc.
Milton Roy Co.
Proportioneers, Inc. (Div., B-I-F Industries, Inc.)
Wallace & Tiernan Inc.

Pumps, Deep Well:
American Well Works
Layne & Bowler, Inc.
Layne & Bowler Pump Co.
Worthington Corp.

Pumps, Diaphragm:
Dorr-Oliver Inc.
W. S. Rockwell Co.
Wallace & Tiernan Inc.

Pumps, Hydrant:
W. S. Darley & Co.
Jos. G. Pollard Co., Inc.

Pumps, Hydraulic Booster:
Ross Valve Mfg. Co.

Pumps, Sewage:
Allis-Chalmers Mfg. Co.
DeLaval Steam Turbine Co.
C. H. Wheeler Mfg. Co.
Worthington Corp.

Pumps, Sump:
DeLaval Steam Turbine Co.
Layne & Bowler Pump Co.
C. H. Wheeler Mfg. Co.
Worthington Corp.

Pumps, Turbine:
DeLaval Steam Turbine Co.
Layne & Bowler, Inc.
Layne & Bowler Pump Co.

Recorders, Gas Density, CO_2, NH_3, SO_2, etc.:
Permutit Co.
Wallace & Tiernan Inc.

Recording Instruments:
Builders-Providence, Inc. (Div., B-I-F Industries, Inc.)
Burgess-Manning Co., Penn Instruments Div.
Infilco Inc.
Simplex Valve & Meter Co.
Wallace & Tiernan Inc.

Reservoirs, Steel:
Bethlehem Steel Co.
Chicago Bridge & Iron Co.
R. D. Cole Mfg. Co.
Graver Tank & Mfg. Co.
Hammond Iron Works
Pittsburgh-Des Moines Steel Co.
Sparling Meter Co.

Sand Expansion Gages; see Gages

Sleeves: see Clamps

Sleeves and Valves, Tapping:
James B. Clow & Sons
M & H Valve & Fittings Co.
Mueller Co.
Rensselaer Valve Co.
A. P. Smith Mfg. Co.

Sludge Blanket Equipment:
General Filter Co.
Graver Water Conditioning Co.
Permutit Co.

Sodium Chloride:
International Salt Co., Inc.

Sodium Fluoride
American Agricultural Chemical Co.

Sodium Hexametaphosphate:
Calgon Co.

Sodium Hypochlorite:
John Wiley Jones Co.
Wallace & Tiernan Inc.

Sodium Silicate:
Philadelphia Quartz Co.

Sodium Silicofluoride
American Agricultural Chemical Co.
Tennessee Corp.

Softeners:
Cochrane Corp.
Dorr-Oliver Inc.
General Filter Co.
Graver Water Conditioning Co.
Hungerford & Terry, Inc.
Infilco Inc.
Permutit Co.
Roberts Filter Mfg. Co.
Walker Process Equipment, Inc.

Softening Chemicals and Compounds:
Calgon Co.
Cochrane Corp.
General Filter Co.
Infilco Inc.
International Salt Co., Inc.
Permutit Co.
Tennessee Corp.

Standpipes, Steel:
Bethlehem Steel Co.
Chicago Bridge & Iron Co.
R. D. Cole Mfg. Co.
Graver Tank & Mfg. Co.

Hammond Iron Works
Pittsburgh-Des Moines Steel Co.

Steel Plate Construction:
Bethlehem Steel Co.
Chicago Bridge & Iron Co.
R. D. Cole Mfg. Co.
Graver Tank & Mfg. Co.
Hammond Iron Works
Pittsburgh-Des Moines Steel Co.

Stops, Curb and Corporation:
Hays Mfg. Co.
Mueller Co.

Storage Tanks: see Tanks

Strainers, Suction:
James B. Clow & Sons
M. Greenberg's Sons
R. D. Wood Co.

Surface Wash Equipment:
Cochrane Corp.
Permutit Co.

Swimming Pool Sterilization:
Builders-Providence, Inc. (Div., B-I-F Industries, Inc.)
Omega Machine Co. (Div., B-I-F Industries, Inc.)
Proportioneers, Inc. (Div., B-I-F Industries, Inc.)
Wallace & Tiernan Inc.

Tanks, Steel:
Bethlehem Steel Co.
Chicago Bridge & Iron Co.
R. D. Cole Mfg. Co.
Graver Tank & Mfg. Co.
Hammond Iron Works
Pittsburgh-Des Moines Steel Co.

Tapping-Drilling Machines:
Hays Mfg. Co.
Mueller Co.
A. P. Smith Mfg. Co.

Tapping Machines, Corp.:
Hays Mfg. Co.
Mueller Co.

Taste and Odor Removal:
Builders-Providence, Inc. (Div., B-I-F Industries, Inc.)
Cochrane Corp.
General Filter Co.
Graver Water Conditioning Co.
Industrial Chemical Sales Div.
Infilco Inc.
Permutit Co.
Proportioneers, Inc. (Div., B-I-F Industries, Inc.)
Wallace & Tiernan Inc.

Turbidimetric Apparatus (For Turbidity and Sulfate Determinations):
Wallace & Tiernan Inc.

Turbines, Steam:
Allis-Chalmers Mfg. Co.
DeLaval Steam Turbine Co.

Turbines, Water:
Allis-Chalmers Mfg. Co.
DeLaval Steam Turbine Co.

Valve Boxes:
James B. Clow & Sons
Ford Meter Box Co.
M & H Valve & Fittings Co.
Mueller Co.
Rensselaer Valve Co.
A. P. Smith Mfg. Co.
Trinity Valley Iron & Steel Co.
R. D. Wood Co.

Valve-Inserting Machines:
Mueller Co.
A. P. Smith Mfg. Co.

Valves, Altitude:
Golden-Anderson Valve Specialty Co.
W. S. Rockwell Co.
Ross Valve Mfg. Co., Inc.
S. Morgan Smith Co.

Valves, Butterfly, Check, Flap, Foot, Hose, Mud and Plug:
Builders-Providence, Inc. (Div., B-I-F Industries, Inc.)
Chapman Valve Mfg. Co.
James B. Clow & Sons
DeZurik Corp.
M. Greenberg's Sons
Kennedy Valve Mfg. Co.
M & H Valve & Fittings Co.
Mueller Co.
Henry Pratt Co.
Rensselaer Valve Co.
W. S. Rockwell Co.
S. Morgan Smith Co.
R. D. Wood Co.

Valves, Detector Check:
Hersey Mfg. Co.

Valves, Electrically Operated:
Builders-Providence, Inc. (Div., B-I-F Industries, Inc.)
Chapman Valve Mfg. Co.
James B. Clow & Sons
Crane Co.
Darling Valve & Mfg. Co.
DeZurik Corp.
Golden-Anderson Valve Specialty Co.
Kennedy Valve Mfg. Co.
M & H Valve & Fittings Co.
Mueller Co.
Henry Pratt Co.
Rensselaer Valve Co.
W. S. Rockwell Co.
A. P. Smith Mfg. Co.
S. Morgan Smith Co.

Valves, Float:
James B. Clow & Sons
Golden-Anderson Valve Specialty Co.
Henry Pratt Co.
W. S. Rockwell Co.
Ross Valve Mfg. Co., Inc.

Valves, Gate:
Chapman Valve Mfg. Co.
James B. Clow & Sons
Crane Co.
Darling Valve & Mfg. Co.
DeZurik Corp.
Dresser Mfg. Div.
Kennedy Valve Mfg. Co.
Ludlow Valve Mfg. Co., Inc.
M & H Valve & Fittings Co.
Mueller Co.
Rensselaer Valve Co.
W. S. Rockwell Co.
A. P. Smith Mfg. Co.
R. D. Wood Co.

Valves, Hydraulically Operated:
Builders-Providence, Inc. (Div., B-I-F Industries, Inc.)
Chapman Valve Mfg. Co.
James B. Clow & Sons
Crane Co.
Darling Valve & Mfg. Co.
DeZurik Corp.
Golden-Anderson Valve Specialty Co.
Kennedy Valve Mfg. Co.
F. B. Leopold Co.
M & H Valve & Fittings Co.
Mueller Co.
Henry Pratt Co.
Rensselaer Valve Co.
W. S. Rockwell Co.
A. P. Smith Mfg. Co.
S. Morgan Smith Co.
R. D. Wood Co.

Valves, Large Diameter:
Chapman Valve Mfg. Co.
James B. Clow & Sons
Crane Co.
Darling Valve & Mfg. Co.
Golden-Anderson Valve Specialty Co.
Kennedy Valve Mfg. Co.
Ludlow Valve Mfg. Co., Inc.
M & H Valve & Fittings Co.
Muller Co.
Henry Pratt Co.
Rensselaer Valve Co.
W. S. Rockwell Co.
A. P. Smith Mfg. Co.
S. Morgan Smith Co.
R. D. Wood Co.

Valves, Regulating:
DeZurik Corp.
Foster Eng. Co.
Golden-Anderson Valve Specialty Co.
Mueller Co.
Henry Pratt Co.
W. S. Rockwell Co.
Ross Valve Mfg. Co.
S. Morgan Smith Co.

Valves, Swing Check:
Chapman Valve Mfg. Co.
James B. Clow & Sons
Crane Co.
Darling Valve & Mfg. Co.
Golden-Anderson Valve Specialty Co.
M. Greenberg's Sons
M & H Valve & Fittings Co.
Mueller Co.
Rensselaer Valve Co.
W. S. Rockwell Co.
A. P. Smith Mfg. Co.
R. D. Wood Co.

Venturi Tubes:
Builders-Providence, Inc. (Div., B-I-F Industries, Inc.)
Burgess-Manning Co., Penn Instruments Div.
Infilco Inc.
Simplex Valve & Meter Co.

Waterproofing:
Barrett Div.
Inertol Co., Inc.
Koppers Co., Inc.

Water Softening Plants: see Softeners

Water Supply Contractors:
Layne & Bowler, Inc.

Water Testing Apparatus:
Wallace & Tiernan Inc.

Water Treatment Plants:
American Well Works
Chain Belt Co.
Chicago Bridge & Iron Co.
Cochrane Corp.
Dorr-Oliver Inc.
Etablissements Degremont
General Filter Co.
Graver Water Conditioning Co.
Hammond Iron Works
Hungerford & Terry, Inc.
Infilco Inc.
Permutit Co.
Pittsburgh-Des Moines Steel Co.
Roberts Filter Mfg. Co.
Walker Process Equipment, Inc.
Wallace & Tiernan Inc.

Well Drilling Contractors:
Layne & Bowler, Inc.

Wrenches, Ratchet:
Dresser Mfg. Div.

Zeolite: see Ion Exchange Materials

A complete Buyers' Guide to all water works products and services offered by AWWA Associate Members appears in the 1957 AWWA Directory.